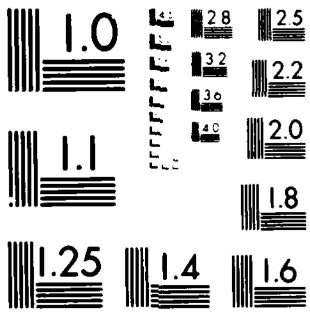
AD-A122 574 HYDROPOWER STUDY BLACKWATER DAM WEBSTER NEW HAMPSHIRE 1/1
(U) CORPS OF ENGINEERS WALTHAM MA NEW ENGLAND DIV
AUG 81

UNCLASSIFIED F/G 10/2 NL

END
DATE
FILMED
DTIC



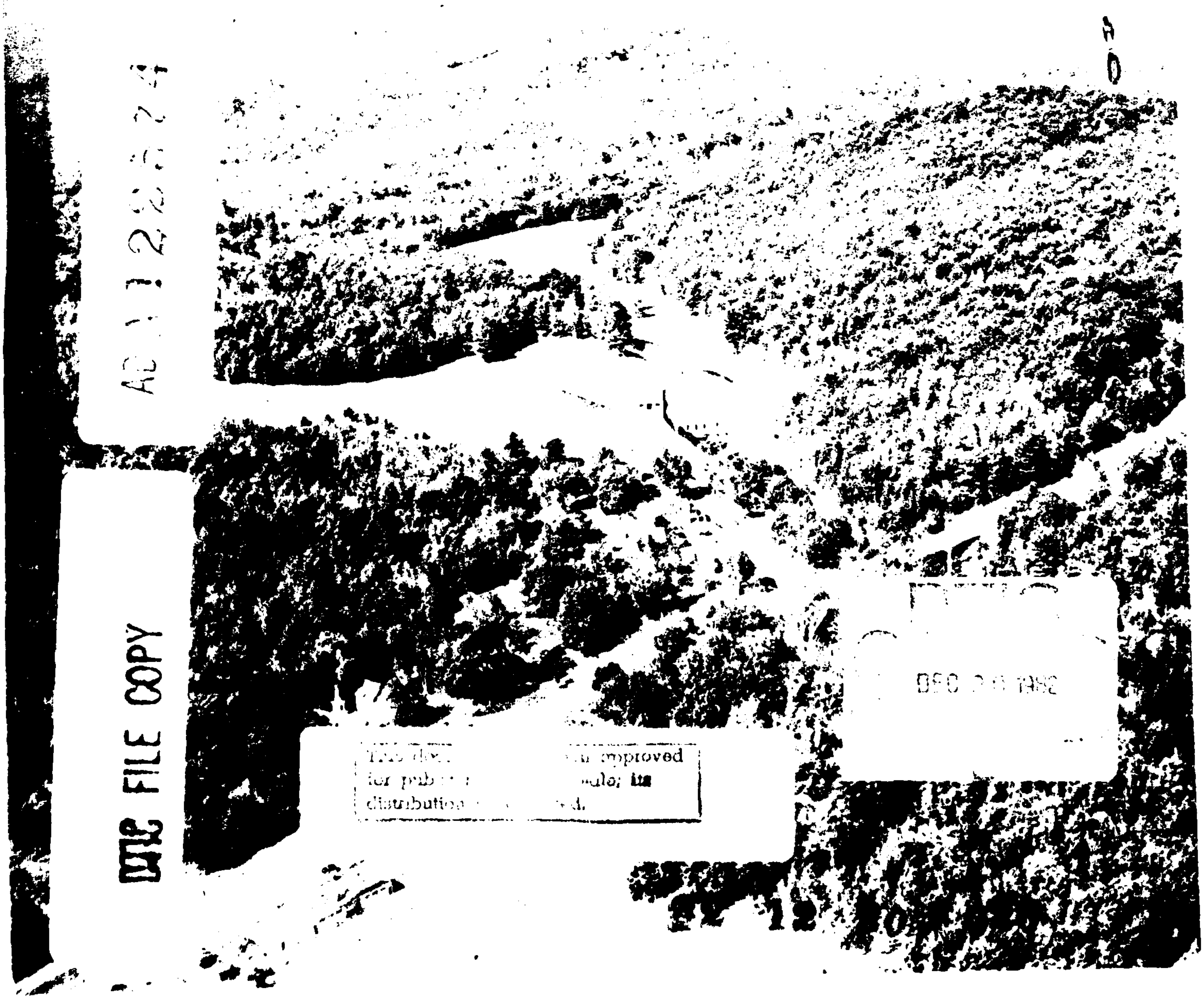
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

Hydropower Study

US Army Corps
of Engineers
New England Division

August 1981

Reconnaissance Report
Blackwater Dam, Webster, New Hampshire



DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

UNCLASSIFIED 2

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER / 2. GOVT ACCESSION NO. A122574	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) HYDROPOWER STUDY, BLACKWATER DAM WEBSTER, NEW HAMPSHIRE	5. TYPE OF REPORT & PERIOD COVERED RECONNAISSANCE REPORT
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) U.S. ARMY, CORPS OF ENGINEERS NEW ENGLAND DIVISION	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS DEPT. OF THE ARMY, CORPS OF ENGINEERS NEW ENGLAND DIVISION, NEDPL 424 TRAPELO ROAD, WALTHAM, MASS. 02254	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE August 1981
	13. NUMBER OF PAGES 50
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: UNLIMITED DISTRIBUTION

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Maps. charts

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hydroelectric power
Hydroelectric plant
Land use
Land management
Water Resources

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Report present the results of a reconnaissance study of the feasibility of adding hydropower facilities to the Army Corps' flood control dam located on the Black Water River in Webster, New Hampshire. The addition of hydrpower facilities has been found to be economically feasible, i.e. 600 kilowatt installation.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

HYDROPOWER STUDY

BLACKWATER DAM

WEBSTER, NEW HAMPSHIRE

RECONNAISSANCE REPORT

AUGUST 1981

US Army Engineer Division, New England
424 Trapelo Road
Waltham, MA 02254

FOREWORD

This report presents the results of a reconnaissance study of the feasibility of adding hydropower facilities to the Corps' flood control dam located on the Blackwater River at Webster, New Hampshire.

Using current Water Resources Council criteria, the addition of hydropower facilities at Blackwater Dam has been found to be economically feasible. It has been found that a 600 kilowatt installation could generate 2013 megawatt-hours annually at a cost of about 69 mills per kilowatt hour. Implementation of this plan would require the creation of a 28-foot-deep, 600 acre lake behind the dam to create a head for power generation. Currently, no permanent pool is maintained at the dam.

Funding and time constraints limited the scope of this effort. Baseline data were gathered from existing literature. Only run-of-river alternatives were considered and previously devised, more complicated plans, involving storage, were not considered. No detailed hydrologic, hydraulic, or reservoir regulation studies were accomplished. Designs and cost estimates prepared for this report are preliminary.

No studies regarding social or environmental acceptability have been undertaken, no environmental assessments have been made, and no marketing issues have been considered. As this study progresses these and other issues will be studied and alternative plans of development will be formulated and evaluated.

BLACKWATER DAM

FIGURE 1

TABLE OF CONTENTS

FIGURES

TABLES

I. INTRODUCTION

Purpose and Authority

This is a reconnaissance report on the feasibility of adding hydropower facilities at the Corps of Engineers flood control dam at Webster, New Hampshire on the Blackwater River. Authority for this study is contained in Section 216 of Public Law 91-611 (the River and Harbor Act of 1970):

> Sec. 216. The Secretary of the Army, acting through the Chief of Engineers, is authorized to review the operation of projects the construction of which has been completed and which were constructed by the Corps of Engineers in the interest of navigation, flood control, water supply, and related purposes, when found advisable due to the significantly changed physical or economic conditions, and to report thereon to Congress with recommendations on the advisability of modifying the structures to their operation, and for improving the quality of the environment in the overall public interest.

Scope of Study

The principal thrust of this limited reconnaissance effort is to determine whether any economically feasible hydropower development could be undertaken at Blackwater Dam. Baseline environmental, recreational, social and cultural conditions in the study area have been identified. Due to time and funding limitations only two alternatives were considered. If the study is continued several alternatives will be evaluated.

Study Participants and Coordination

This study was conducted by the New England Division, Corps of Engineers. Informal telephone communications with various State and local officials provided much useful data. The Federal Energy Regulatory Commission also provided input to this report.

The Report and Study Process

This reconnaissance report is the product of the first of three study stages which the Corps uses for planning potential projects. In subsequent study stages alternative plans will be formulated, evaluated, and finally an implementable plan may be identified and submitted to Congress for authorization and construction.

The multiobjective planning framework utilized by the Corps in its studies is designed to insure that a complete and systematic evaluation is accomplished. Problems, needs, concerns and opportunities are identified

and addressed. Plans are formulated and evaluated and impacts are assessed. Public input is sought throughout the study and efforts are made to keep the public informed of the study progress and significant findings. The approaches used for this study are consistent with the President's Water Resources Council's "Principles and Standards" and the National Environmental Policy Act of 1969.

As the study progresses, in-depth data will be developed to allow increasingly detailed evaluation and assessment of alternatives until it is possible to identify the best alternatives from both environmental and economic development viewpoints. Ultimately, using the study findings and public involvement, a plan judged to be in the best public interest will be identified.

Other Studies

In 1939, before construction of Blackwater Dam, the Corps of Engineers undertook a brief study of the hydropower potential of the site. At that time it was found that a peaking project having an installed capacity of 10,000 KW could be economically developed if a higher dam and penstock were built and a large conservation pool were maintained to provide storage hydropower generation. This concept is discussed later in the report.

Early in 1981, Water Power Development Corporation of Nashua, New Hampshire, was granted preliminary permit #3303 by the Federal Energy Regulatory Commission. This permit allows Water Power Development Corporation to study the dam. After studies the firm could apply for a license to operate a hydropower facility at the dam. It may be found, however, that it is in the public interest for the Federal Government to operate such a project. Decisions of this type will be made by either the Federal Energy Regulatory Commission or the Congress depending on the circumstances. Water Power Development Corporation is studying four alternatives according to its application for a preliminary permit.

There are no other known hydropower studies at Blackwater Dam. The Corps of Engineers completed a Master Plan for Reservoir Development in 1967 and a Review of Operations of the Project in 1976.

II. PROBLEM IDENTIFICATION

National and Regional Objectives

The primary purpose of the hydropower addition under consideration is to reduce regional (and national) dependence on oil for energy generation. Currently 60 percent of New England's electrical energy is produced at oil-fired generating plants. A hydropower addition to this project would displace oil generated energy, thereby reducing dependence on oil. Any hydropower plans developed would have to be technically, environmentally, economically and socially acceptable. Any opportunities to enhance environment which would result from a hydropower addition will be investigated and implemented where possible.

Existing Conditions in the Study Area

Physical Setting

The Blackwater Dam is a flood control project owned and operated by the U.S. Army Corps of Engineers. Located on the Blackwater River, about 8.6 miles above its confluence with the Contoocook River, the dam and reservoir lie within the corporate boundaries of Webster and Salisbury, Merrimack County, New Hampshire. A general plan and vicinity map are shown on Figure 2.

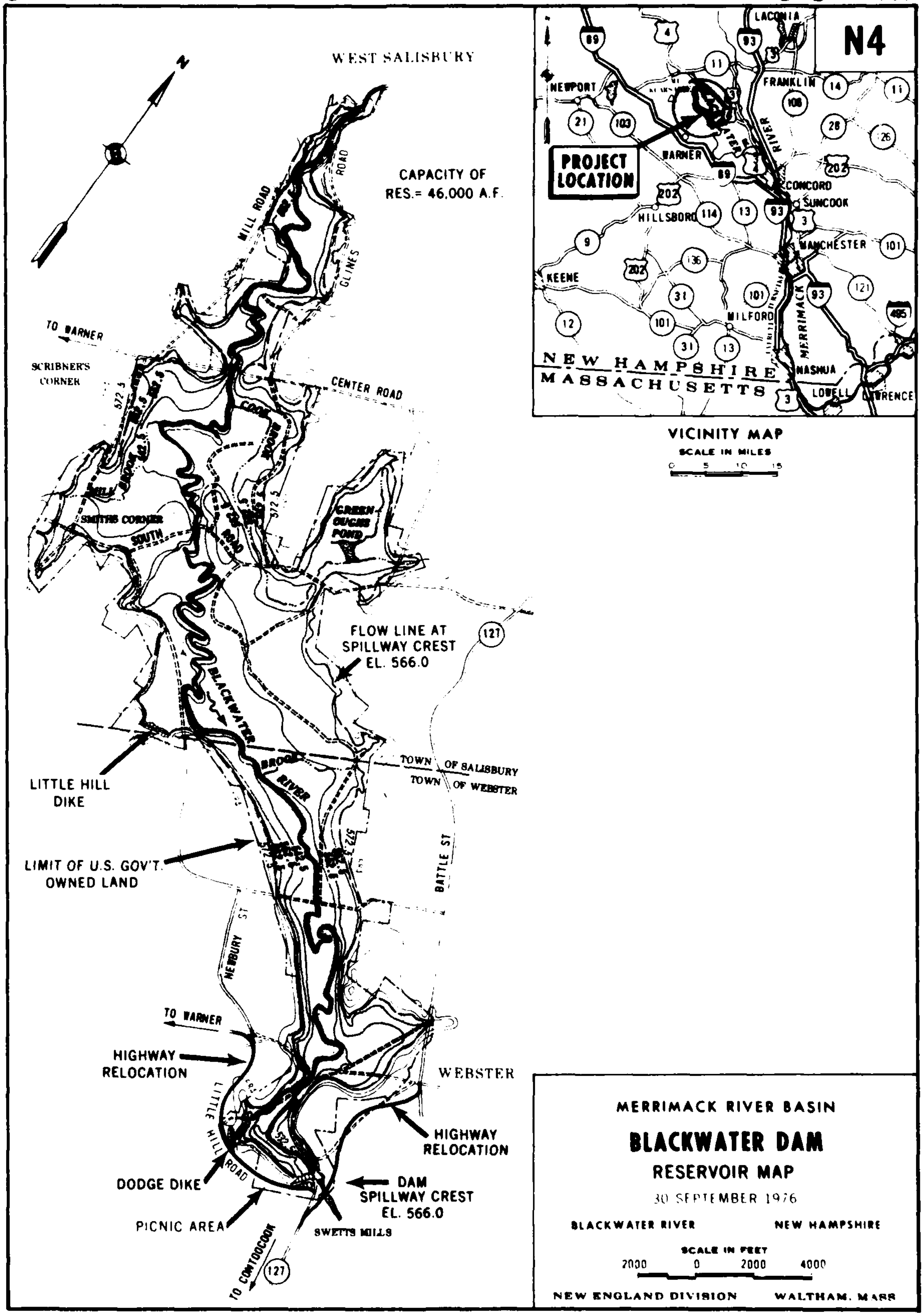
The major physical components of the project are an earth dam, two earth dikes, and a concrete spillway and outlet works. Pertinent data for Blackwater Dam are summarized on Table 1.

The spillway consists of a concrete gravity-type ogee section which extends from the left abutment 240 feet across the river at elevation 566 feet above the National Geodetic Vertical Datum (NGVD). A 16-foot penstock intake was incorporated into the dam to allow for future hydropower additions.

The outlet works, located in the concrete spillway section, consist of three gated outlets, each 3'-6" wide x 5'-3" high, and one ungated outlet 3'-6" wide , 6'-6" high, with inverts at elevation 515 feet NGVD. The ungated outlet is plugged. A general plan and elevation of the dam is shown on Figure 3.

The storage capacity of Blackwater Dam totals 46,000 acre-feet when filled to spillway crest. This is equivalent to 6.74 inches of runoff from the 128-square mile drainage area, and would create a pool covering 3,280 acres.

CORPS OF ENGINEERS U. S. ARMY



MERRIMACK RIVER BASIN

BLACKWATER DAM

RESERVOIR MAP

30 SEPTEMBER 1976

BLACKWATER RIVER NEW HAMPSHIRE

SCALE IN FEET

2000 0 2000 4000

NEW ENGLAND DIVISION WALTHAM, MASS

FIGURE 2

TABLE 1

PERTINENT DATA - BLACKWATER DAM

Location	Blackwater River, Webster and Salisbury, Merrimack County, New Hampshire
Drainage Area	128 square miles
Storage Use	Flood Control

Reservoir Storage

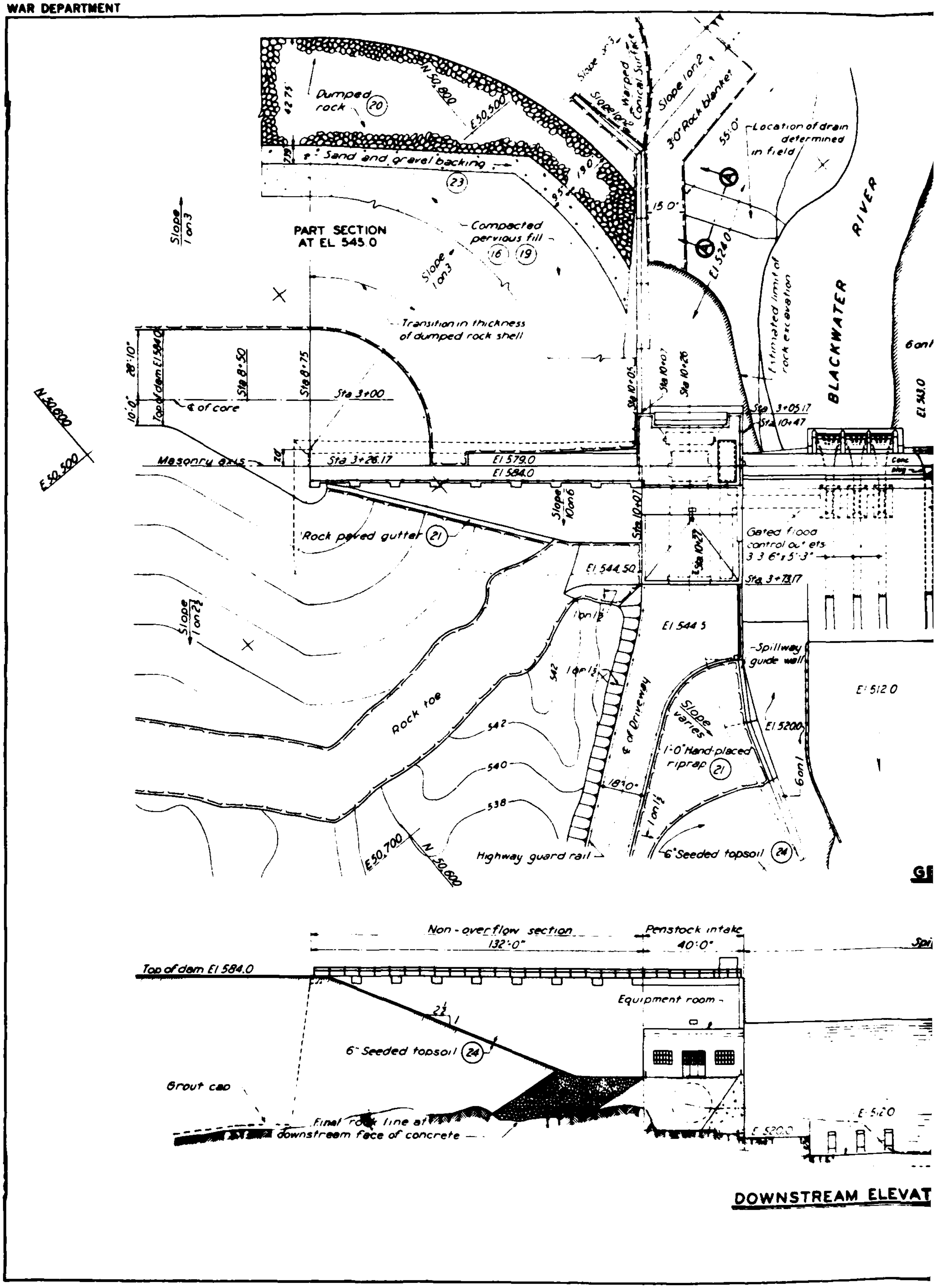
	Stage (ft, msl)	Area (acres)	Capacity Acre-Feet	Capacity Inches on Drainage Area
Inlet Elevation	515	0	0	0
Spillway Crest	566	3,280	46,000	6.74
Maximum Surcharge	579	4,030	47,400 (net)	6.94 (net)

Embankment Features	
Type	Rolled earth fill
Length (feet)	1,150
Top Width (feet)	38.8
Top Elevation (ft, NGVD)	584
Height (feet)	75

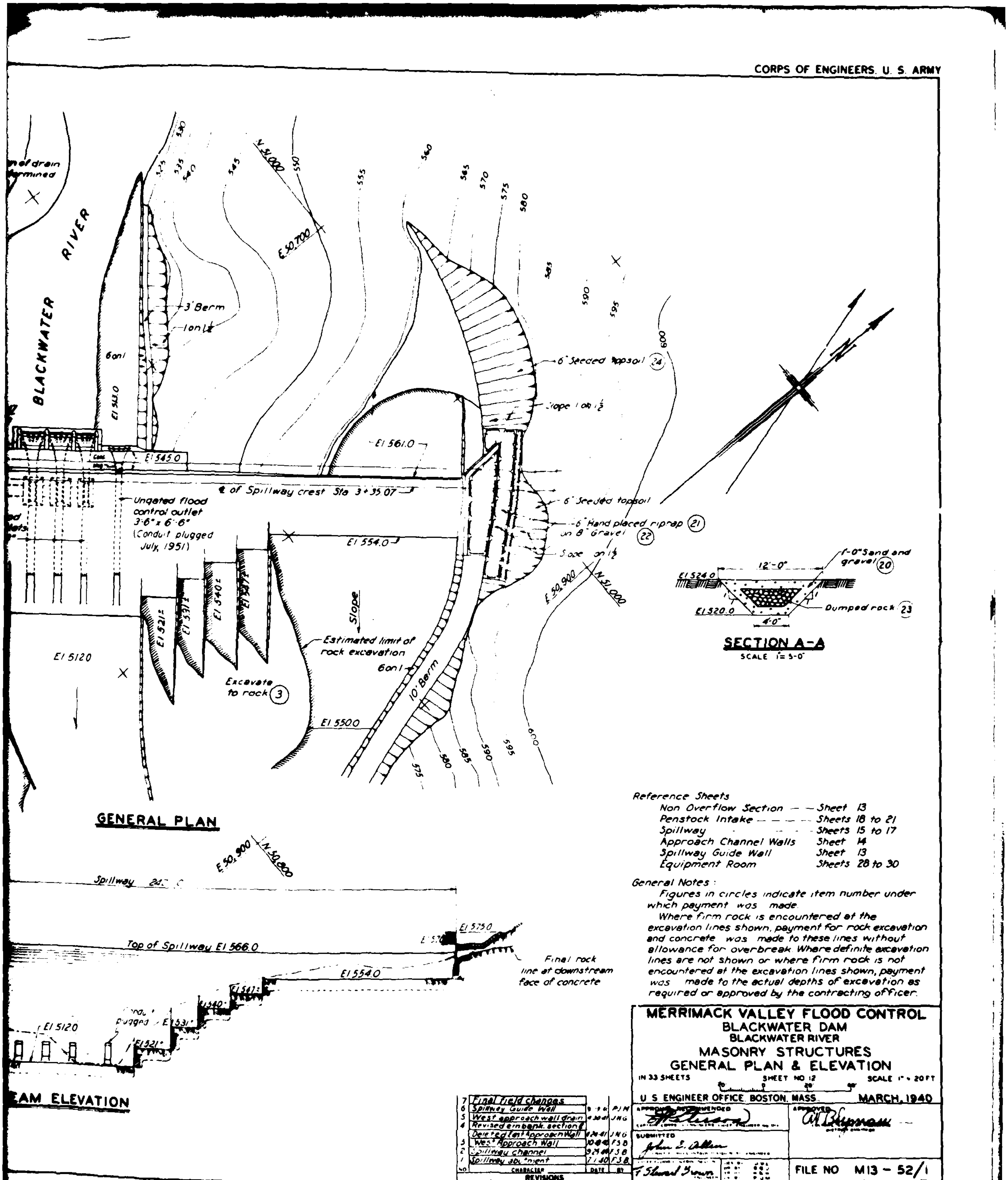
Spillway	
Location	Left abutment
Type	Gravity type, ogee section
Crest Length (feet)	240
Crest Elevation (ft, NGVD)	566

Outlet Works	
Type	4 rectangular conduits (3 gated, 1 plugged)
Conduit Inside Dimensions (feet)	3.5 x 5.25 and one 3.5 x 6.5 (plugged)
Conduit Length (feet)	65
Service Gate Type	Three hydraulic gates
Service Gate Size (feet)	Three 3.5 x 5.25
Penstock Intake Diameter (feet)	16
Downstream Channel Capacity (cfs)	2,300
Maximum Discharge Capacity (Spillway Crest Elevation)	2,800 cfs
Stilling Basin	None

Lands	3,580 acres have been purchased in fee (to elev 566)



Dumped rock (20)
Sand and gravel backing (23)
PART SECTION AT EL 545.0
Compacted pervious fill (16) (19)
Slope 1 on 3
Transition in thickness of dumped rock shell
Warped conical surface
Slope 1 on 2
3'-0" Rock blanket
Location of drain determined in field
Estimated limit of rock excavation
BLACKWATER RIVER
N 50,800
E 50,500
N 50,600
E 50,500
Top of dam El 584.0
℄ of core
Sta 8+50
Sta 8+75
Sta 3+00
Masonry axis
Sta 3+26.17
El 579.0
El 584.0
Sta 10+05
Sta 10+07
Sta 10+26
Sta 3+05.17
Sta 10+47
Slope 1 on 6
Sta 10+07
Sta 10+27
Rock paved gutter (21)
El 544.50
Gated flood control outlets 3 3'6" x 5'3"
Sta 3+73.17
Slope 1 on 2½
El 544.5
Spillway guide wall
El 512.0
El 520.0
Rock toe
℄ of Driveway
Slope varies
1'-0" Hand-placed riprap (21)
542
540
538
18'-0"
6 on 1
E 50,700
N 50,600
Highway guard rail
6" Seeded topsoil (24)
Non-overflow section
132'-0"
Penstock intake
40'-0"
Top of dam El 584.0
Equipment room
6" Seeded topsoil (24)
Grout cap
Final rock line at downstream face of concrete
El 520.0
DOWNSTREAM ELEVAT



CORPS OF ENGINEERS, U. S. ARMY
BLACKWATER RIVER
3' Berm
1 on 1½
6 on 1
El 513.0
El 545.0
E 50,700
N 51,000
6" Seeded topsoil (24)
Slope 1 on 1½
El 561.0
℄ of Spillway crest Sta 3+35.07
Ungated flood control outlet 3'-6" x 6'-6" (Conduit plugged July, 1951)
6" Seeded topsoil
6" Hand placed riprap (21) on 8" Gravel (22)
Slope on 1½
El 554.0
E 50,900
N 51,000
El 521±
El 531±
El 540±
El 547±
Slope
El 512.0
Estimated limit of rock excavation
6 on 1
Excavate to rock (3)
10' Berm
El 550.0
SECTION A-A
SCALE 1" = 5'-0"
El 524.0
El 520.0
12'-0"
4'-0"
1'-0" Sand and gravel (20)
Dumped rock (23)
GENERAL PLAN
E 50,900
N 50,800
Spillway
El 575.0
Top of Spillway El 566.0
El 554.0
Final rock line at downstream face of concrete
El 547±
El 540±
El 531±
El 521±
El 512.0
Conduit plugged
UPSTREAM ELEVATION
Reference Sheets
Non Overflow Section — Sheet 13
Penstock Intake — Sheets 18 to 21
Spillway — Sheets 15 to 17
Approach Channel Walls — Sheet 14
Spillway Guide Wall — Sheet 13
Equipment Room — Sheets 28 to 30
General Notes:
Figures in circles indicate item number under which payment was made.
Where firm rock is encountered at the excavation lines shown, payment for rock excavation and concrete was made to these lines without allowance for overbreak. Where definite excavation lines are not shown or where firm rock is not encountered at the excavation lines shown, payment was made to the actual depths of excavation as required or approved by the contracting officer.
MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER DAM
BLACKWATER RIVER
MASONRY STRUCTURES
GENERAL PLAN & ELEVATION
IN 33 SHEETS
SHEET NO 12
SCALE 1" = 20 FT
U. S. ENGINEER OFFICE, BOSTON, MASS.
MARCH, 1940
7 Final field changes
6 Spillway Guide Wall
5 West approach wall drain
4 Revised embank. section
Deleted East Approach Wall
3 West Approach Wall
2 Spillway channel
1 Spillway abutment
REVISIONS
SUBMITTED
APPROVED
FILE NO M13 - 52/1

FIGURE 3

The Blackwater River originates at the outflow of Pleasant Lake in New London, New Hampshire, and flows southeasterly, for a distance of thirty miles between Ragged Mountain and Mount Kearsarge, through the Blackwater Dam to its confluence with the Contoocook River. The Blackwater River has a drainage area of 136 square miles. The basin is essentially rural and little development has taken place. The Blackwater is part of the Merrimack River Basin which drains an area of about 5,015 square miles. Figure 4 shows the entire Merrimack Basin and the Blackwater Basin. Figure 5 shows a profile of the entire Merrimack Basin. Located in the north central portion of the Merrimack Basin the average annual temperature in the Blackwater Basin is 43°F with daily temperatures ranging from infrequent highs over 100°F to occasional lows below -30°F. Generally the Blackwater Basin is characterized by steep hills and mountains with relatively narrow valleys and floodplains. Lakes, ponds and swamps make up about 6 percent of the drainage area. The average annual precipitation is about 44 inches. Distribution of precipitation is rather uniform throughout the year, but during the winter months most of the precipitation is in the form of snow. Average annual snowfall in the project area is in the 80 to 90 inch range. Water content in the snow cover varies from 5 to 7 inches, usually reaching a maximum about the middle of March. Based on 47 years of streamflow records on the Blackwater River at Webster, New Hampshire, the maximum annual runoff was 34 inches in 1973 and the minimum annual runoff was nine inches in 1965. The average flow at the dam is about 213 cfs.

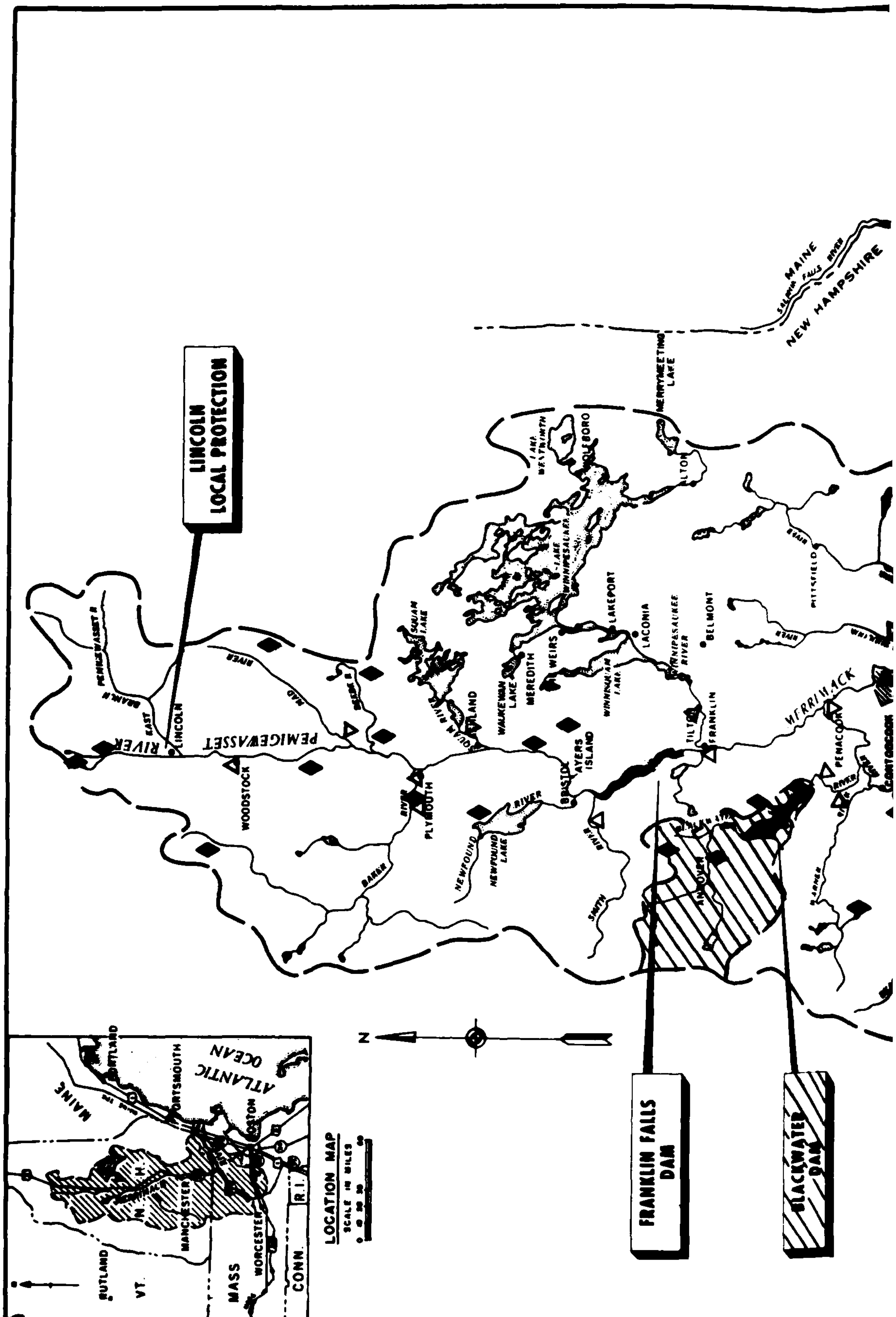
Within the flowage easement of the reservoir the Blackwater River meanders through a valley bottom that is relatively flat (elevation 515 feet). This condition extends for only a short distance from the banks of the river before gentle slopes take over and extend to the boundaries of the Blackwater Flood Control Reservoir. Portions of the valley bottom and gentler slopes are cleared and used for pasturage under lease. Otherwise, the valley and slopes are heavily wooded. The river usually flows freely through the dam in a relatively natural state. However, during times of high runoff the area behind the dam becomes a large reservoir holding back floodwaters. Figure 6 is a topographic map showing the project area.

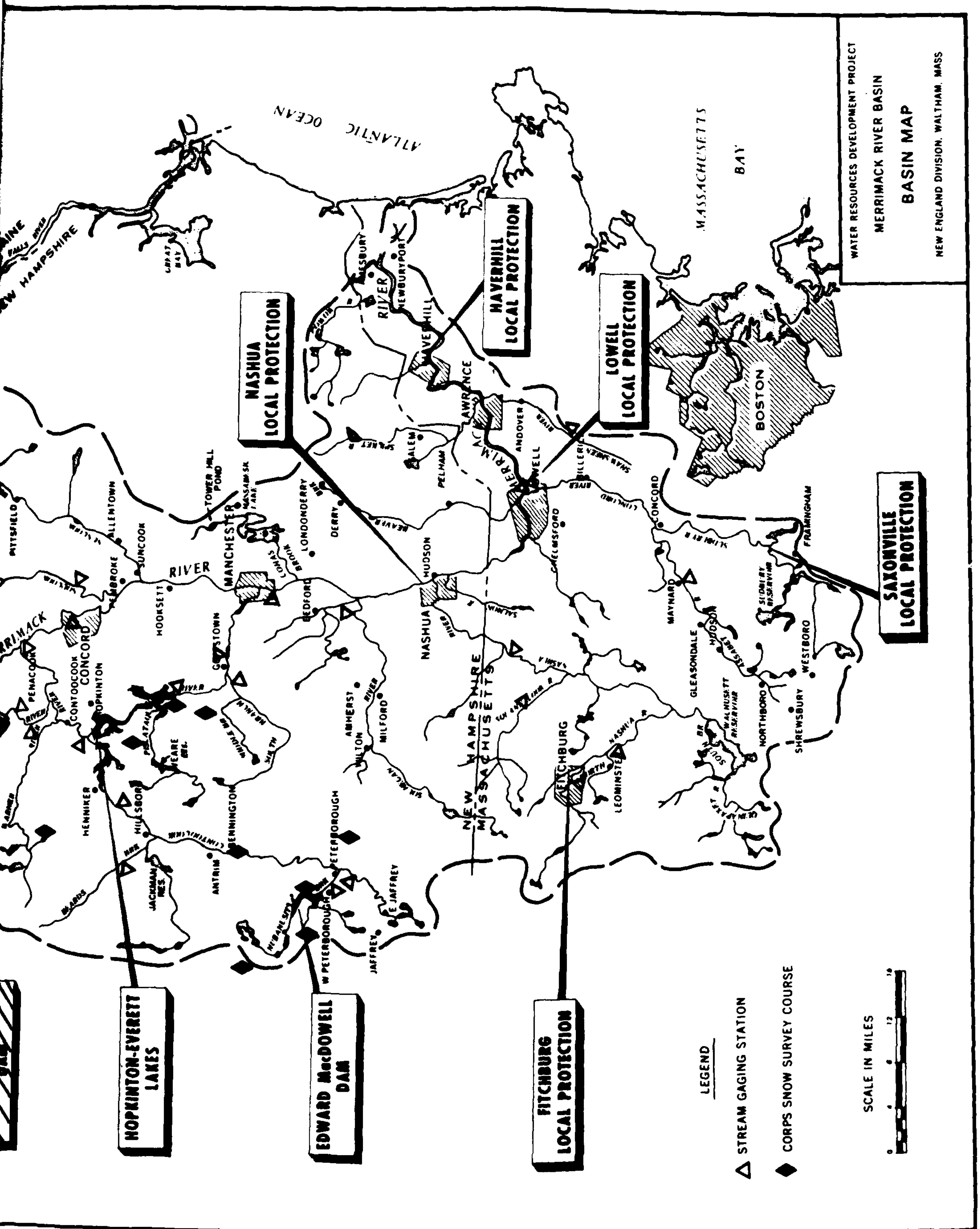
The soil series found along the Blackwater River in the project area is the Hinckley-Windsor-AuGres Association, known to be sandy and gravelly and low in agricultural value. The upland areas have deep sandy, very stony soils of the Gloucester series, with boulders and rock outcrops being common.

Environmental Setting

Water Quality

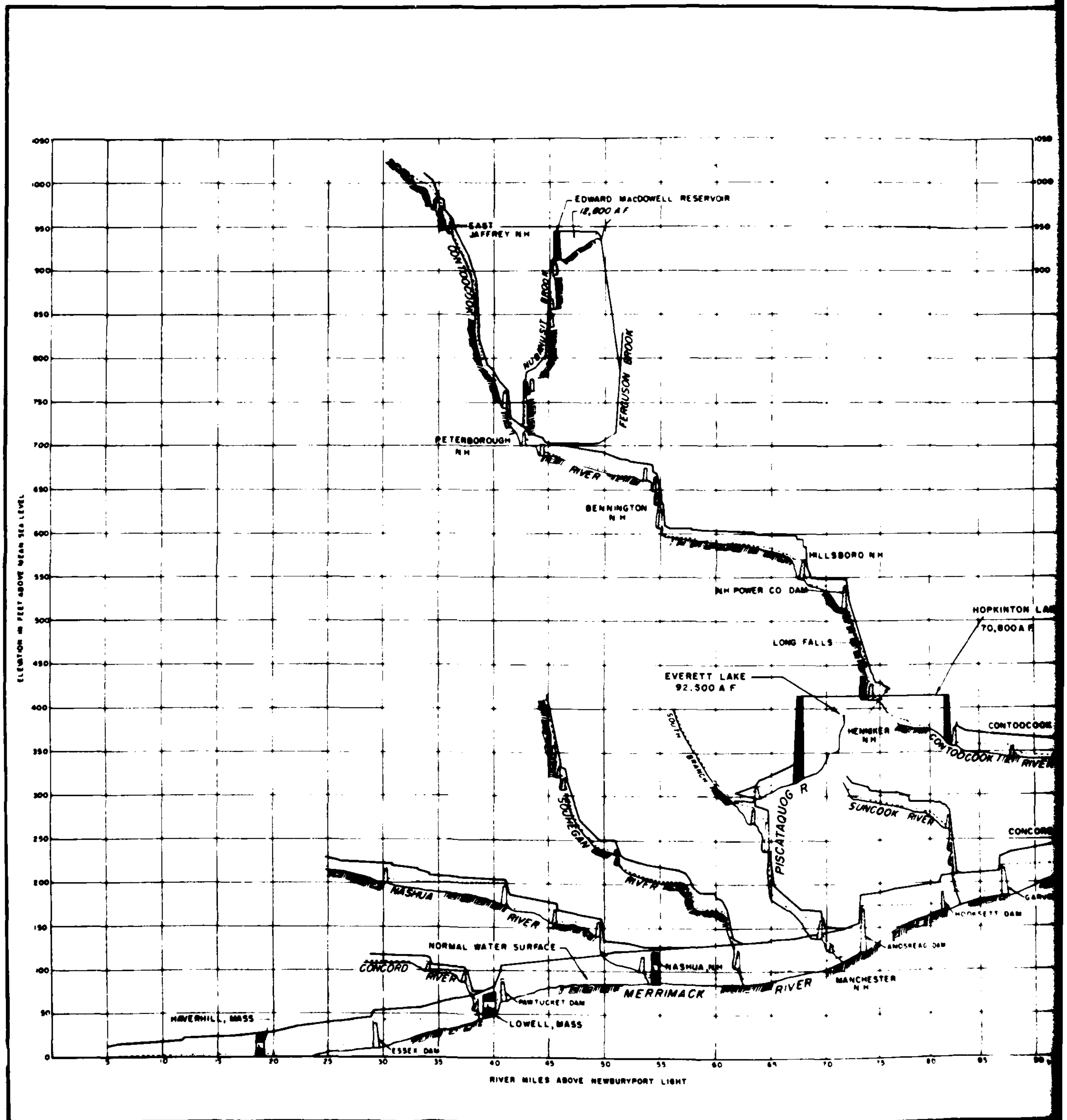
The Blackwater River is deep and slow moving with an average width of 100 feet as it meanders approximately 14 miles through the project. The waters of the Blackwater River and its tributaries are assigned the Class A objective classification by the State of New Hampshire. Under New Hampshire


LINCOLN
LOCAL PROTECTION
FRANKLIN FALLS
DAM
BLACKWATER
DAM
LOCATION MAP
MAINE
NEW HAMPSHIRE
PEMIGEWASSET
RIVER
LINCOLN
WOODSTOCK
PLYMOUTH
BRISTOL
AYERS
ISLAND
NEWFOUND
LAKE
SQUAM
LAKE
MEREDITH
WEIRS
LAKEPORT
LACONIA
BELMONT
WOLFEBORO
MERRYMEETING
LAKE
TILTON
FRANKLIN
PENACOOK
PITTSFIELD
SMITH
BAKER
MAD
MERRIMACK
ATLANTIC
OCEAN
PORTSMOUTH
PORTLAND
MANCHESTER
WORCESTER
BOSTON
RUTLAND
VT.
N. H.
MASS
CONN.
R.I.
NEW YORK



WATER RESOURCES DEVELOPMENT PROJECT
MERRIMACK RIVER BASIN
BASIN MAP
NEW ENGLAND DIVISION, WALTHAM, MASS.
NASHUA LOCAL PROTECTION
HAVERHILL LOCAL PROTECTION
LOWELL LOCAL PROTECTION
SAXONVILLE LOCAL PROTECTION
HOPKINTON-EVERETT LAKES
EDWARD MacDOWELL DAM
FITCHBURG LOCAL PROTECTION
LEGEND
STREAM GAGING STATION
CORPS SNOW SURVEY COURSE
SCALE IN MILES
ATLANTIC OCEAN
MASSACHUSETTS BAY
BOSTON
NEW HAMPSHIRE
MASSACHUSETTS
MANCHESTER
CONCORD
NASHUA
LOWELL
LAWRENCE
HAVERHILL
NEWBURYPORT
FITCHBURG
LEOMINSTER
FRAMINGHAM
PETERBOROUGH

FIGURE 4


EDWARD MacDOWELL RESERVOIR
12,800 A F
EAST JAFFREY N H
CONTOOCOOK
NUBANUSIT BROOK
FERGUSON BROOK
PETERBOROUGH N H
RIVER
BENNINGTON N H
HILLSBORO N H
NH POWER CO DAM
HOPKINTON LAKE
70,800 A F
LONG FALLS
EVERETT LAKE
92,500 A F
SOUTH BRANCH
HENNIKER N H
CONTOOCOOK RIVER
PISCATAQUOG R
SUNCOOK RIVER
SOUHEGAN RIVER
NASHUA RIVER
NORMAL WATER SURFACE
NASHUA, NH
CONCORD RIVER
PAWTUCKET DAM
MERRIMACK RIVER
MANCHESTER N H
HOOKSETT DAM
AMOSKEAG DAM
HAVERHILL, MASS
LOWELL, MASS
ESSEX DAM
ELEVATION IN FEET ABOVE MEAN SEA LEVEL
RIVER MILES ABOVE NEWBURYPORT LIGHT

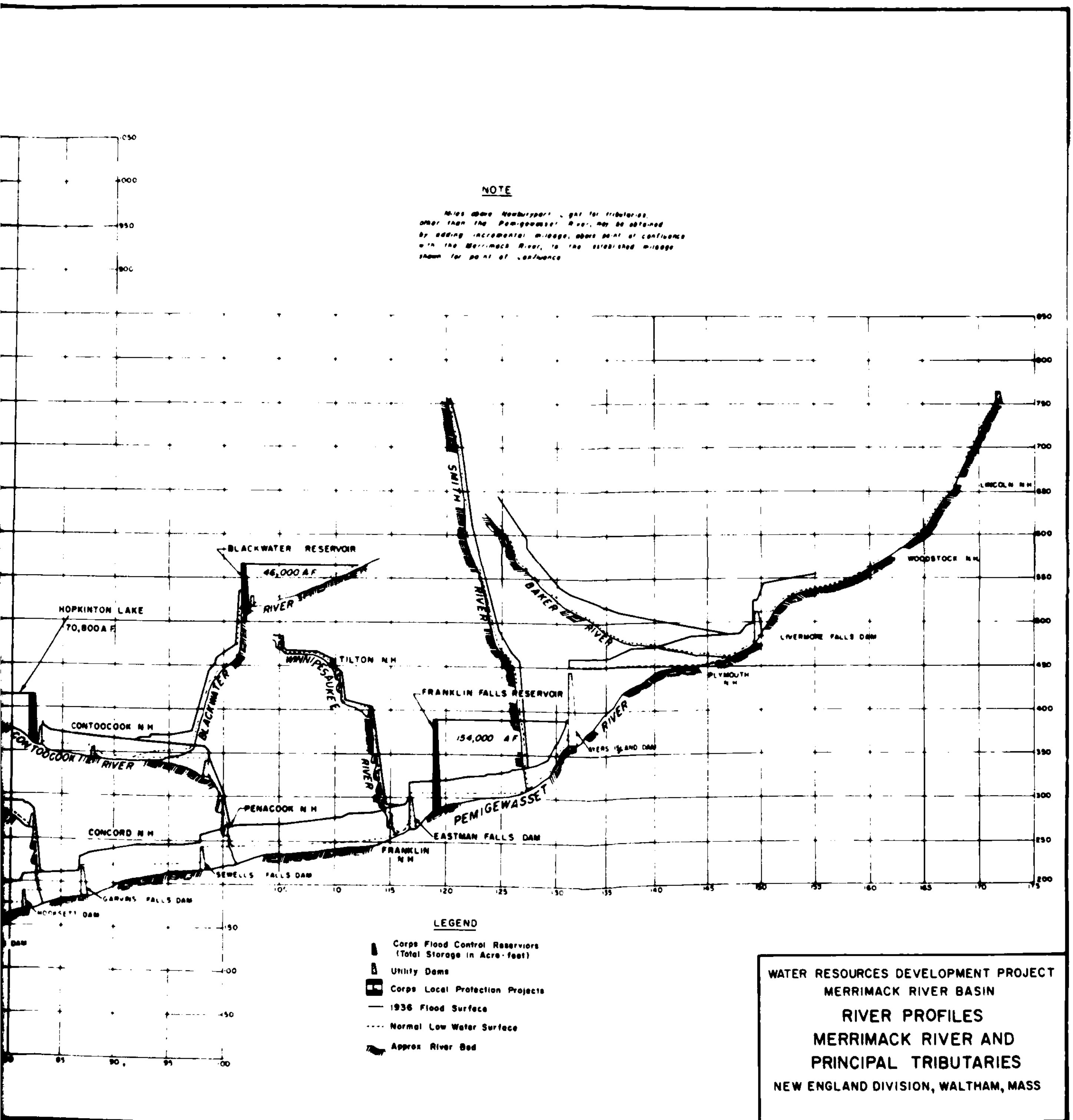
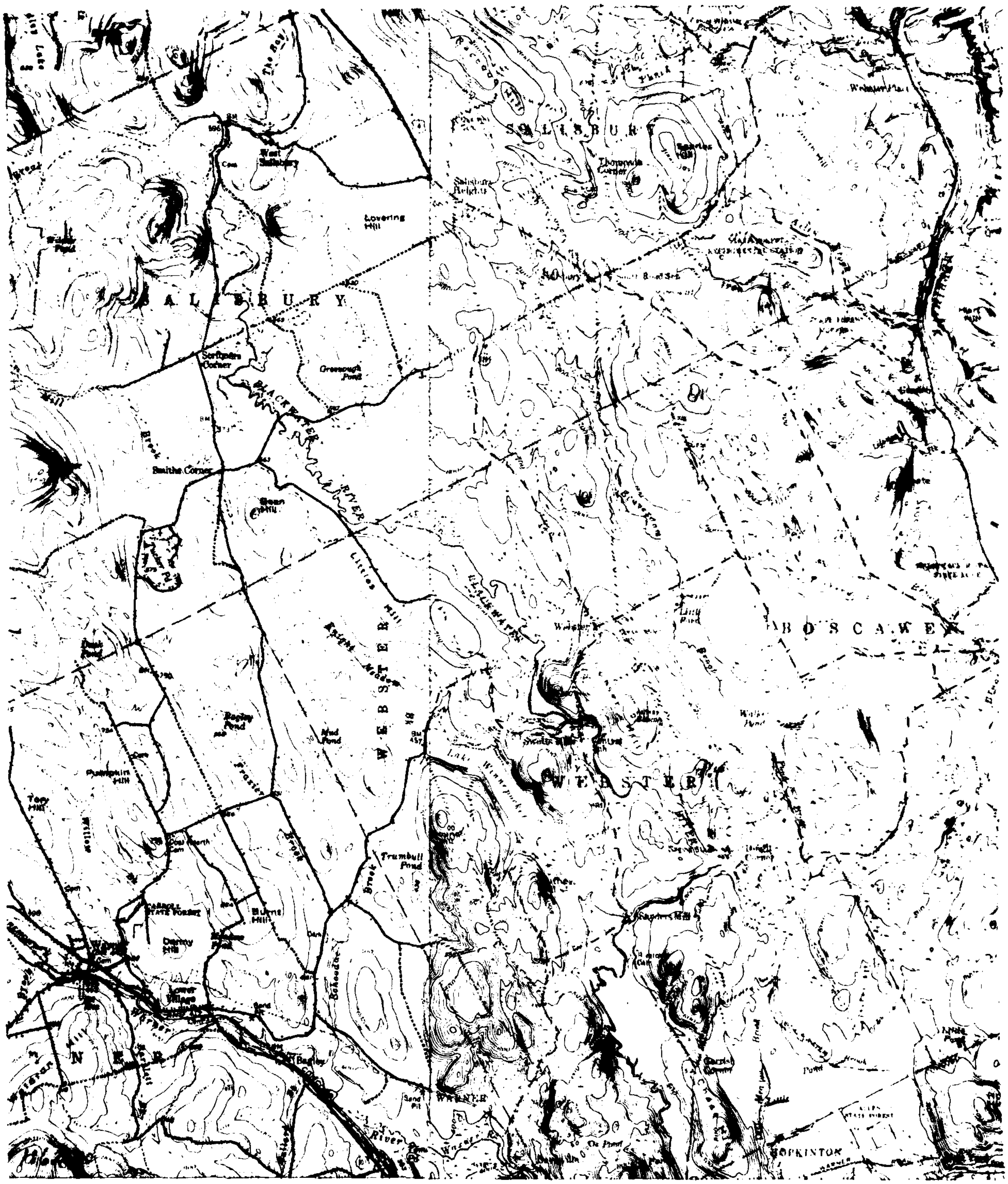

NOTE
BLACKWATER RESERVOIR
46,000 A F
HOPKINTON LAKE
70,800 A F
CONTOOCOOK N H
CONTOOCOOK RIVER
BLACKWATER
RIVER
WINNIPESAUKEE
RIVER
TILTON N H
SMITH
RIVER
BAKER
RIVER
FRANKLIN FALLS RESERVOIR
154,000 A F
PENACOOK N H
CONCORD N H
EASTMAN FALLS DAM
FRANKLIN N H
SEWELLS FALLS DAM
GARVINS FALLS DAM
HOOKSETT DAM
PEMIGEWASSET
RIVER
AYERS ISLAND DAM
PLYMOUTH N H
LIVERMORE FALLS DAM
WOODSTOCK N H
LINCOLN N H
LEGEND
Corps Flood Control Reservoirs (Total Storage in Acre-feet)
Utility Dams
Corps Local Protection Projects
1936 Flood Surface
Normal Low Water Surface
Approx River Bed
WATER RESOURCES DEVELOPMENT PROJECT
MERRIMACK RIVER BASIN
RIVER PROFILES
MERRIMACK RIVER AND
PRINCIPAL TRIBUTARIES
NEW ENGLAND DIVISION, WALTHAM, MASS

FIGURE 5



S A L I S B U R Y
West Salisbury
Lovering Hill
Greenough Pond
Smiths Corner
Bean Hill
BLACKWATER RIVER
Knights Meadow
W E B S T E R
Mud Pond
Pumpkin Hill
Tory Hill
Trumbull Pond
Burnt Hill
B O S C A W E N
HOPKINTON

FIGURE 6

standards, Class A waters are of uniformly excellent quality and are "potentially acceptable for water supply uses after disinfection" as well as all other less stringent uses. There can be no discharge of sewage, wastes or other polluting substances into the waters. Class A waters do not have less than 6 ppm of dissolved oxygen (DO), or less than 75 percent of DO saturation. There are no pH or color limits except as they naturally occur. Turbidity levels must not be more than 5 standard units while coliform levels cannot be more than 50 coliforms per 100 ml unless naturally occurring.

Recent information obtained from the New Hampshire Water Supply and Pollution Control Commission (NHWSPCC) has indicated that the actual water quality condition in the area of the dam is Class B. In the absence of known point source discharges upstream from the dam, it is assumed that the river is degraded to this condition by nonpoint sources. Under New Hampshire standards, Class B waters are acceptable for recreation, fish habitat and fishing and for water supply only after adequate treatment. Parameters are somewhat similar to the Class A designation except for those involving coliform bacteria (not more than 240 coliforms/100 ml) and turbidity (not to exceed 10 standard units for cold water fisheries and 25 standard units in warm water fisheries). Other parameter limits are also relaxed (such as pH, oil and grease, odors, sludge deposits) but cannot be distinguished from Class A standards except in a qualitative way.

Data have been collected by the Corps since 1970 at three different sampling areas: upstream from the project on Blackwater River, on a small tributary of the Blackwater, Mill Brook, and just downstream from the dam. Analysis of the data indicates that although a majority of the classification criteria are met, violations have occurred for the parameters of dissolved oxygen and total coliform.

The dissolved oxygen saturation limits were violated on about 8 percent of the sampling dates on the Blackwater River upstream from the project and about 3 percent of the sampling dates downstream from the project. Very few data have been collected on total coliform, but of those collected, results show that violations have occurred on about 60 percent of the sampling dates.

Data collected on metals show very few problems with the exception of iron and manganese. Data collected for iron indicate that limits on iron for drinking water were violated on 40 to 50 percent of the sampling dates, while those limits placed on manganese were violated in about 5 percent of the samples.

Nutrient loading generally has been low, although a few total phosphorus data points have exceeded the threshold levels for algae blooms (greater than 0.1 mg/l phosphorus). pH levels for the project normally range between 6.4 and 7.0 while data collected on hardness indicate that the water is very soft, as is typical of most New England streams.

Aquatic Ecosystem

The Blackwater River, classified as one of the best trout streams in the southern portion of the State, is stocked annually by the New Hampshire Fish and Game Department with brook, brown and rainbow trout. There is high fishing pressure on the river with an estimated 50 percent return on released fish. Other species found in the river include chain pickerel (Esox niger), brown bullhead (Ictalurus nebulosus), white perch (Morone americana), smallmouth bass (Micropterus dolomieui), pumpkinseed sunfish (Lepomis gibbosus) and bluegill (Lepomis macrochirus).

Terrestrial Ecosystem

Most of the land of Blackwater Dam and Reservoir is in forest cover. Predominant forest species are white pine (Pinus strobus) and hemlock (Tsuga canadensis). Associated hardwoods include sugar maple (Acer saccharum), gray birch (Betula populifolia) yellow birch (Betula lutea), paper birch (Betula papyrifera), and red oak (Quercus rubra). Along the river quaking aspen (Populus tremuloides), red alder (Alnus rubra) and willow (Salix, sp) are dominant.

The project serves as habitat for a variety of resident and migrating wildlife. White-tailed deer (Odocoileus virginianus) is the only "big game" species occurring commonly. Occasionally a black bear (Ursus americanus) is found in the area. Other resident species include the red fox (Vulpes fulva), snowshoe hare (Lepus americanus), gray squirrel (Sciurus carolinensis), raccoon (Procyon lotor), muskrat (Ondatra zibethica), mink (Mustela vison), beaver (Castor canadensis), ruffed grouse (Bonasa umbellus), woodcock (Philohela minor) and ring-necked pheasant (Phasianus colchicus). Waterfowl do breed in the reservoir area. Black duck (Anas rubripes), wood duck (Aix sponsa), hooded merganser (Lophodytes cucullatus) and mallard (Anas platyrhynchos) are the main species present during the nesting season. In general, there is moderate to heavy hunting pressure on the project lands. Trapping is primarily for muskrat, mink and beaver.

Threatened and Endangered Species

Currently there are no Federally listed threatened or endangered species known to occur in the project area (US Fish and Wildlife Service, personal communication).

Cultural, Social and Economic Setting

Recreation and Natural Resources

The average annual visitation at this project over the past six years has been about 45,000 people and has been holding fairly steady. The major recreational activites in the project area at present

expressed as the percentage of total visitation are: sightseeing - 32 percent, swimming - 22 percent, snowmobiling - 11 percent, hunting - 6 percent, picnicking - 5 percent, and fishing - 4 percent. Present recreational facilities consist of an overlook and parking area at the dam, 20 miles of snowmobile trails and six picnic sites, along with numerous access points for hunters and fishermen. There are no swimming facilities, however considerable informal use takes place in local swimming holes in the river.

Historical and Archaeological Resources

The Merrimack River drainage was a major thoroughfare for prehistoric inhabitants travelling between the interior of present day New Hampshire and the coast. Further, anadromous fish formerly ascended the Merrimack and its tributaries, including the Blackwater, in large numbers. This seasonally available resource would have been attractive to Indians in the region, and their fishing camp sites have been found near falls on the major rivers. Therefore, although there are no recorded prehistoric archaeological sites within the Blackwater Dam project area, unrecorded sites are likely to be present. Much of the Blackwater Valley within the project is composed of well-drained gravelly terraces, which would have been ideal camping spots for Indians travelling through or living within the valley throughout the entire prehistoric period.

Historic period occupation of the Blackwater Dam project area consisted primarily of small farms scattered through the valley. Small concentrations of settlement occurred in the vicinity of Swetts Mills and Webster Hill in Webster and Smith's Corner in Salisbury. Approximately 20 farmstead sites, three former cemetery locations, a meeting hall site and a sawmill site are recorded within the property limits of Blackwater Dam. Most of these appear on 19th century maps, and some may have been occupied in the 18th century. Other unrecorded 18th or early 19th century sites may also be present.

Population

From 1930 to 1960 Webster showed a growth rate of 26.9 percent which was slightly higher than that of both the county and state. By 1980, with an increase of 138.9 percent since 1930, Webster has grown by a factor of three times that of Merrimack County and the State of New Hampshire. This increase in residents between 1960 and 1980 can be attributed to the residential development of the Pillsbury Lake Area during the late 1960's. In addition, Webster has become a bedroom community. More people seeking to leave city living find Webster to be a convenient location. While rural residential in nature with little industry of its own, the town borders a major city, Concord, on it southeast border.

Salisbury also showed a growth rate slightly higher than both the county and state. Between 1930 and 1980 Salisbury's population increased by 123.1 percent. However, Salisbury's growth rate was lower than Webster's. Salisbury is mainly agricultural and has recently been becoming more residential. The town is slowly evolving into a bedroom community for people who wish to escape city living but wish to remain within proximity of the major city, Concord. In fact, a large number of the non-farming residents of both Salisbury and Webster are employed in Concord. Yet, planners are presently attempting to limit growth through zoning restrictions on development. Population figures for the town, county, and state are presented in Table 2.

TABLE 2

Population
Salisbury, Webster and Merrimack County, New Hampshire

	Salisbury	% Change	Webster	% Change	Merrimack County	% Change	N.H.	% Change
1930	350		360		56152		465293	
1940	368	5.1	351	-2.5	60710	8.1	491524	5.6
1950	423	14.9	386	10.0	63022	3.8	533242	8.5
1960	415	-2.0	457	18.4	67785	7.6	606291	13.7
1970	589	41.9	680	48.8	80925	19.4	737681	21.7
1980	781	32.6	1092	60.6	98038	21.2		24.5

Land Use

Webster's area totals approximately 18,715 acres or 29.2 square miles with a density of 37.4 persons per square mile in 1980. In the early 1970's forest land accounted for close to 84.3 percent of the total acres. Agriculture constitutes the second largest use of land. Of the 1.2 percent which is developed, the majority was residential. Between 1950 and 1975, Webster showed a decrease in agriculture while development and forest land usage increased. In the early 1950's Webster did not contain any independent residential development; all structures were farm houses or farm related structures. However, by the early 1970's independent residential areas had been constructed contributing to development in Webster.

Salisbury's area totals approximately 24[illegible]5 acres or 38.2 square miles with a density of 20.4 persons per squa[illegible] mile in 1980. Like Webster, forest land constitutes the majority o[illegible] land usage, about 87.9 percent; and agriculture accounts for the second largest use. Between 1950 and 1975 Salisbury showed a decrease in agriculture while idle land increased by almost 219 percent. This idle land is expected to be used for residential development in the future. Land use data are presented in Table 3.

TABLE 3

Land Use
Salisbury and Webster, New Hamsphire
Early 1950's and 1970's

Categories	Early 1950's Salisbury	Webster	Early 1970's Salisbury	Webster	% Change Early 1950's - 1970's Salisbury	Webster
Agriculture	2,534	2,555	1,975	1,927	-24.6	-24.6
Idle[1]	190	460	606	724	218.9	57.4
Forest	21,370	15,624	21,513	15,513	.7	1.0
Developed[2]	0	0	0	76	0	217.0
Other[3]	381	76	281	217	0	0
Total	24,475	18,715	24,475	18,715	0	0

[1]Idle includes land which was formerly agricultural and still has not been developed.
[2]Developed includes residential, industrial, commercial and recreational usage.
[3]Other includes wetlands.

Economy

The town of Webster contains two manufacturing businesses - Mellon Company and Yankee Pinecraft Furniture, and two commercial establishments. Salisbury has no industrial development and only one commercial establishment. Therefore, many nonfarming residents of these towns have jobs situated elsewhere in Merrimack County; a large number of these residents are employed in Concord. Statistics presented in Table 4 show employment by industry in 1979 for Merrimack County. Of those employed, the largest number, about 22.6 percent, were found in manufacturing. Manufacturing was followed by the government as the second largest employer. About 77.3 percent of those employed by the government worked for the State and local governments. Employment in services and trade were also of importance for the county.

TABLE 4

Employment by Industry
Merrimack County, 1979

Industry	Number Employed	Percent of Total
Proprietors	3,716	7.7
Farm	180	.4
Ag. Serv., For., Fish and Other	148	.3
Mining	78	.2
Construction	2,017	4.2
Manufacturing	10,816	22.5
Transportation & Public Utilities	1,092	2.3
Wholesale/Retail Trade	7,756	16.2
Fin., Ins., and R.E.	2,923	6.1
Services	8,668	18.1
Government	10,570	22.0
Total	47,964	100.0

The most likely population of Salisbury and Webster as presented by the New Hampshire Office of State Planning suggests a population increase as seen in Table 5 below.

TABLE 5

Projected Population Growth

Year	Salisbury	Webster
1985	905	1,265
1990	1,000	1,424
1995	1,104	1,604
2000	1,181	1,742

A population of 1,742 in the year 2000 would be a 59.5 percent increase from Webster's 1980 population while a population of 1,181 in Salisbury in 2000 would be a 51.2 percent increase from its 1980 population. There is an increase in population as more people live outside the nearest large cities, such as Concord, and commute to work. Furthermore, some of the expected growth in Webster and Salisbury will result from the overflow from the rapidly growing counties of Hillsborough and Rockingham. However, growth will be partially limited by regulations set forth by the town planners. Through their limitations on building permits, the planners of these towns desire to control growth in a manner not to exceed the capacity for providing the expanded services to support such growth.

Future growth in Webster and Salisbury, New Hampshire, will occur mainly in terms of residential growth. Residential growth is expected to occur in single family and mobile homes. Business, commerical or industrial expansion will be discouraged in Salisbury and Webster. In fact, business, commerical and industrial uses are prohibited in Webster unless permitted special exemptions by the Board of Adjustment. The desire of town planners remains to preserve and improve the attractiveness of the towns of Webster and Salisbury as rural residential and farming communities, to continue their desirability as places in which to live and do business and to promote the health, welfare, morals, convenience and safety of their citizens.

Reservoir Regulation

The principal objective of the Blackwater Dam and Reservoir is FLOOD CONTROL: the protection of communities downstream on the Blackwater and Contoocook Rivers; and in conjunction with Hopkinton-Everett and Franklin Falls Reservoirs, it provides protection for the major industrial, commercial and residential centers along the Merrimack River such as Concord, Manchester, Nashua, Lowell, Lawrence and Haverhill.

The three gates at Blackwater Dam are normally maintained at an opening of 3′ -3′ -3′, which will automatically throttle releases during an unexpected river rise. During minor rises, gate changes will not normally be made unless instructions are issued by the Corps Reservoir Control Center, located in Waltham, Massachusetts.

During flood periods all flood control gates at Blackwater Dam are throttled or closed, if necessary, to reduce flood stages on the Blackwater, Contoocook and Merrimack Rivers. Regulation at the dam is coordinated with other flood control reservoirs in the Merrimack Basin to obtain optimum effectiveness of the entire system. A minimum release rate of about 20 cfs is maintained during periods of regulation in order to sustain downstream fish life.

Following the downstream recession of the flood on the Merrimack River, stored floodwaters are released as rapidly as possible, consistent with amounts of reservoir storages utilized, downstream flows, channel capacities, weather forecasts and travel times. The maximum nondamaging channel capacity downstream of the dam is 2,300 cfs. Releases of this magnitude are not usually made unless considerable flood control storage is utilized. When releases exceed 2,000 cfs, downstream conditions are periodically inspected. Increases in discharge should not exceed 300 cfs per hour until 1,800 cfs is reached, then 100 cfs increments until nondamaging channel capacity is attained.

During the release phase, the levels at downstream points should not exceed flood stage; however, during an unusual flood, it is possible

that flood stages may continue to be exceeded due to runoff from uncontrolled downstream tribuaries and it may be necessary to begin releases once the stage has crested.

Ordinarily during a major flood, the gates would not be opened to avoid spillway discharge. Surcharge storage above the spillway crest would be utilized if downstream channel capacities continue to be exceeded by runoff from uncontrolled areas. However, if the stage in the reservoir continued to rise above the crest with the possibility of endangering the structural integrity of the dam, releases might be made through the gates. Under such circumstances State and local police would be advised of the threat.

In order to minimize the possibility of slumping banks in the reservoir area, the maximum rate of reservoir drawdown should not exceed about 10 feet in 24 hours. During freezing season, no releases will be initiated until an appraisal of downstream ice conditions has been made.

It is conceivable that an extraordinary situation may arise, such as: drowning, dam or bridge failure, highway or railroad washout, ice jam or debris deposit. Since the purpose of the reservoir is to save lives and prevent or reduce damage, regulation during such unusual conditions may not follow previously described rules, but will be governed by the urgency of the circumstances. During such situations the project generally is shut down immediately.

It is the policy of the Corps of Engineers to cooperate with downstream water users and other interested parties or agencies. The Project Manager may be requested by downstream users to deviate from normal regulation for short periods. Whenever such a request is received, the manager shall ascertain the validity of the request and obtain assurances for other downstream water users that they are agreeable to the proposed operation.

Future Conditions Without the Project

No significant changes in the physical, environmental, cultural, social and economic conditions are anticipated in the study area. No significant changes in reservoir regulation are envisioned. However, the projected gradual growth could result in subtle changes in the environment and water quality.

Problems, Needs and Opportunities

New England depends heavily on oil for its electricity. About 60 percent of the region's electricity is produced at oil-fired generating stations. Given the instability of oil supplies and the fluctuating prices associated with them, the need for the development of renewable resource projects is apparent. The addition of hydropower at Blackwater Dam would reduce the region's dependence on oil for the production of electricity.

Planning Constraints

General planning constraints and guidance for this investigation are contained in Public Law 91-190, National Environmental Policy Act; Public Law 91-611, River and Harbor and Flood Control Act of 1970; Public Law 92-500, Federal Water Pollution Control Act Amendments of 1972; Public Law 93-251, Water Resources Development Act of 1974 PL 95-217, Clean Water Act; and the Water Resources Council's, "Principles and Standards for Planning Water and Related Land Resources."

Specific guidance is found in the following Department of the Army regulations; ER 1105-2-14, ER 1105-2-50, ER 1105-2-210, ER 1105-2-220, ER 1105-2-230, ER 1105-2-240, ER 1105-2-250, ER 200-2-2, ER 1105-2-800 and ER 1102-2-921.

The primary purpose of this project is flood control and any hydropower addition planned should not significantly interfere with that purpose.

In the design of any hydropower addition, measures must be taken, to the extent possible, to minimize environmental and social disruptions. Since there are no known endangered species in the project area consultation under Section 7 of the Endangered Species Act of 1973 (PL 93-205) will not be required.

A funding constraint severely limited the scope of studies associated with this reconnaissance report. The preliminary hydrologic studies associated with assumptions regarding the infringement on existing flood control storage and impacts on reservoir regulation activities as well as design and cost estimates reflect this limitation. Future studies will include detailed hydrologic and reservoir regulation studies to determine whether this proposed infringement on flood control storage or any loss of storage will have a significant adverse impact on flood control protection within the Merrimack River Basin. For this report assumptions have been made assuming the Corps would plan, develop, construct and operate the hydropower addition.

Problem and Opportunity Statements

The hydropower addition being considered would provide an opportunity over the next 50 years to:

- Increase New England's energy supply and the nation's energy independence
- Develop and utilize a native renewable energy resource to its maximum potential
- Increase fisheries and migratory waterfowl habitat.

III. FORMULATION OF PLANS

Management Measures

There are a number of management measures which may be employed to reduce New England's dependence on oil for the production of electrical energy and to satisfy other planning objectives as well. Structural measures include conversion of oil fired facilities to coal, building additional coal and nuclear facilities, construction of hydroelectric and tidal power projects, and development of alternative energy sources including, but not limited to wind, passive solar, coal liquification or gasification photovoltaics, wave action, geothermal, wood, other biomass, and purchases of imported power. Non-structural measures would consist mainly of conservation and load management. A brief discussion of the primary function of each measure, including inherent advantages and disadvantages, is presented below.

Conversion of oil facilities to use coal as a fuel directly reduces the amount of oil needed for electric energy production. The concept is technically sound and economically implementable at many facilities. The conversion, however, is not without problems. Key factors that must be considered are the availability of water or rail transportation facilities and protection of ambient environmental quality.

The construction of new coal and nuclear facilities also directly reduces oil use. New coal facilities have problems similar to converted facilities and the current social-political climate in New England makes development of nuclear projects difficult.

Hydroelectric facilities including run-of-river, pumped storage, conventional and tidal power, also directly reduce the amount of oil used for generation. While these projects do not degrade air quality, or create dangerous waste materials they tend to permanently alter existing physical conditions at the project site. Sometimes they displace inhabitants and adversely affect resident wildlife. The fuel, water, is a renewable resource.

Wind power is one of the oldest forms of energy. Wind power is clean and many sites are available. Energy from such projects is intermittent, as is energy from single pool tidal power projects and run-of-river hydropower projects. Energy from such projects is dependent on natural phenomena, wind, tides and runoff. Man cannot control when fuel will be available. In the case of tidal power or run-of-river power energy availabilty can be predicted with a reasonable accuracy. Wave action offers promise on a small scale. Active solar is basically an at site technology which is useful for space and hot water heating. Passive solar design generally decreases the energy needs of a structure but does not generate energy. Liquified coal, photovoltaics, nuclear fusion and biomass will, perhaps, be the predominant energy sources of the 2000's. Once fully developed, these technologies could lead to energy independence for the Nation.

Purchases of imported power would reduce our direct dependence on oil but do little to enhance our energy independence.

Conservation is perhaps the best short term answer to oil use reduction. Lower thermostat settings, insulation and other conservation methods directly reduce oil use and have limited impacts on changes on life style.

Load management is primarily aimed at rearranging the timing of electric demand. This involves the changing of people's habits. Once established, load management would allow more use of base load and intermediate power sources (lower cost coal, nuclear and hydroelectric) and require less peaking power (expensive pumped storage and oil dependent combustion turbines). Of course, load management assumes that nuclear and coal energy sources will continue to be developed and ultimately displace existing oil generating facilities.

Plan Formulation Rationale

The purpose of this investigation is to determine the feasibility of adding hydropower facilities to the Blackwater Dam. Due to the limited scope of this report, it was decided that only run-of-river hydropower alternatives would be considered. Two alternatives were formulated. Both are intended to displace a combined cycle oil-fired thermal facility. One is a multiple unit installation which increases energy output and the other is a lower cost single unit installation. Both alternatives require the creation of a 28-foot deep permanent pool to provide head. No attempts were made to determine the potential positive effect that storage could have on hydropower operations. Both alternatives are planned as run-of-river projects, and fluctuations in the pool will be less than 2 feet.

Owing to the existence of installed generating capacity downstream further studies of storage type hydropower facilities appear to be warranted if the study is continued. The only reason such studies have not been accomplished for this report is the limited scope of this study.

Plans of Others

As previously mentioned, Water Power Development of Nashua, New Hampshire currently holds a Federal Energy Regulatory Commission preliminary permit on Blackwater Dam. According to their application they plan to study four alternatives:

1. Install a 443 kw unit at the dam to generate 1.77 million kwh annually.

2. Construct a 300-foot penstock, building a powerhouse with an installed capacity of 886 kw to generate 3.54 million kwh annually.

3. Construct a 2-mile long penstock, build a powerhouse with an installed capacity of 3,249 kw to generate 13 million kwh annually.

4. Construct a 2-mile long penstock, build a powerhouse with an installed capacity of 2,800 kw to generate 11.2 million kwh annually.

Description of Plans

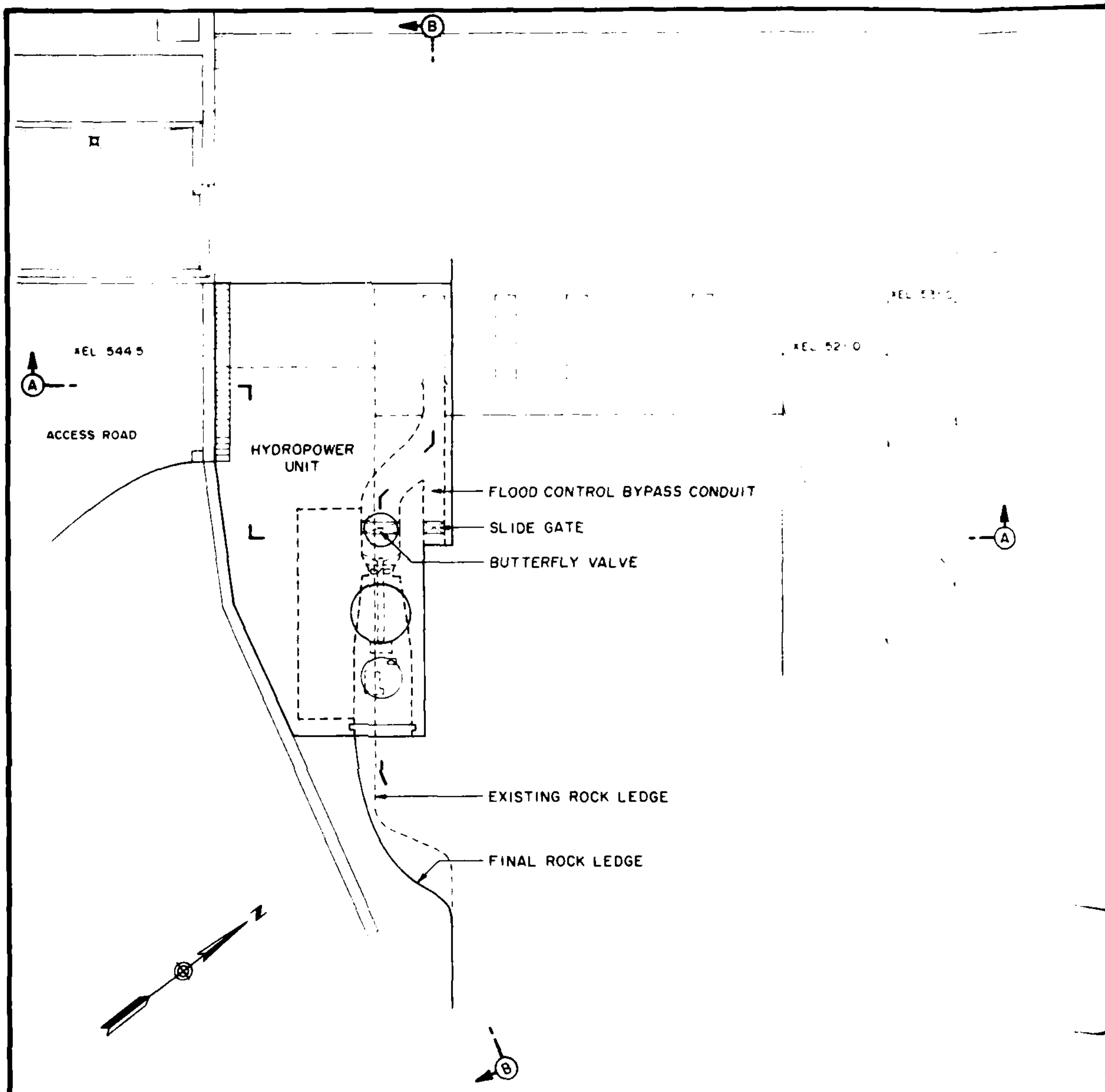
Two run of the river hydropower alternatives were considered for this report. Alternative 1 is a plan of hydropower development at Blackwater Dam with a hydraulic head of 30 feet. At pool elevation 543 feet NGVD, a pool depth of 28 feet represents 4,720 acre-feet of lost flood control storage equivalent to .7 inch of runoff from the contributing watershed. The plan would use one of the flood control outlets as a penstock to permit discharge to a single hydropower unit at the toe of the spillway. This alternative would have a hydraulic capacity of 295 cfs and generating capacity of 600 kilowatts, providing a computed average annual generation of 2,013 megawatt hours. A sketch of this plan is shown as Figure 7. Outflows varying from 118 to 310 cfs would be used for generation, and the project would be operating at full design capacity about 20 percent of the year, generally occurring during March, April, or May.

When the inflow is less than 110 cfs, generation would cease and outlet discharge would be maintained approximately equal to inflow. With this plan there would be no generation approximately 55 percent of the time, generally occurring during the low flow period July through October.

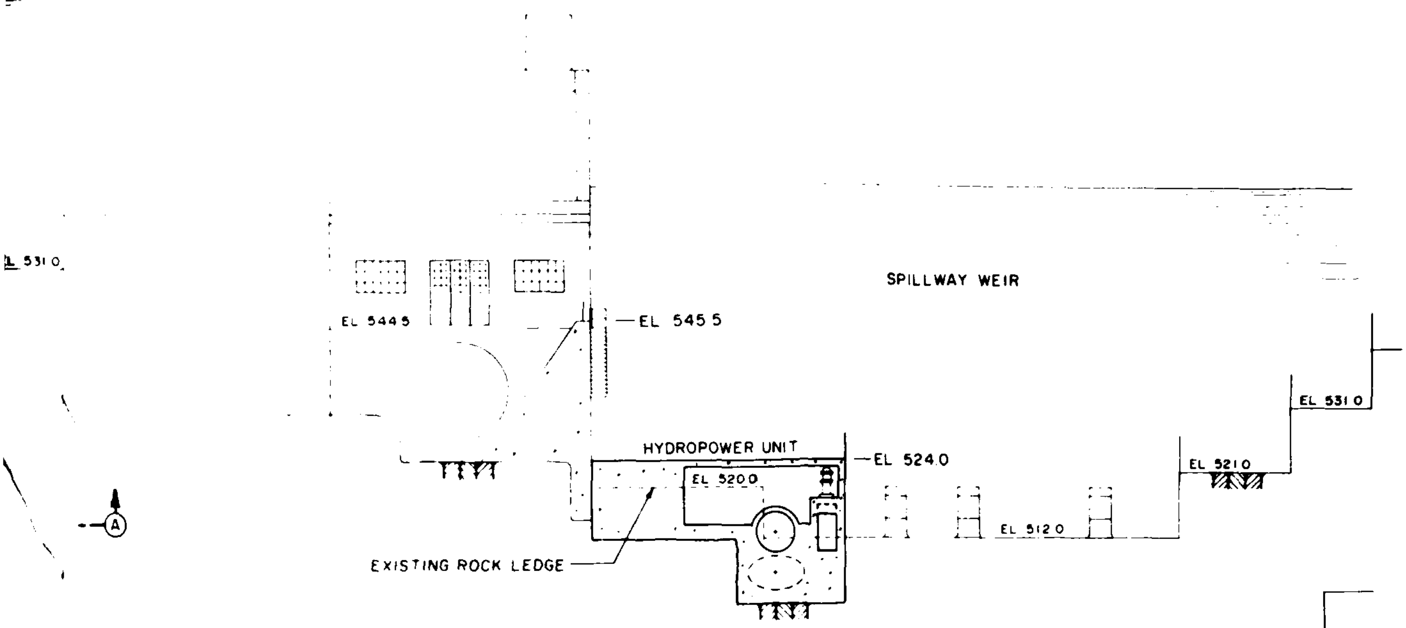
Alternative 2 is similar to Alternative 1 except two hydropower turbines would be installed instead of one. The twin hydropower units would have a combined capacity of 354 cfs and generating capacity of 720 kilowatts. This plan would provide a computed average annual generation of 2,512 megawatt-hours. A sketch of this plan is shown on Figure 8.

When the inflow is less than 70 cfs, generation would cease and outlet discharge would be maintained approximately equal to inflow. With this plan there would be no generation about 37 percent of the year generally occurring during the late summer. Outflows varying from 70 to 370 cfs would be used for generation, and the project would be operating at full design capacity about 16 percent of the year generally in March, April, or May.

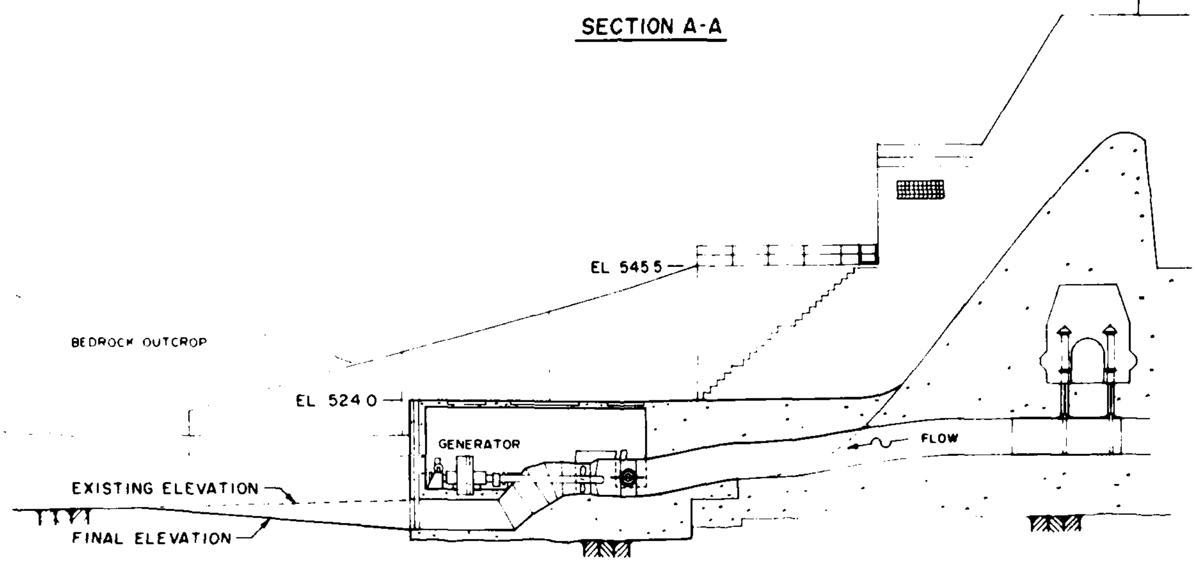
For either alternative the powerhouse would be located at the base of the spillway adjacent to the parking lot. The existing spillway and the existing parking lot retaining wall will be used as powerhouse walls. A bifurcation will be provided in the powerhouse to direct water to the turbine(s) from the extended, steel lined, flood control outlet conduit.


EL 544.5
ACCESS ROAD
HYDROPOWER UNIT
FLOOD CONTROL BYPASS CONDUIT
SLIDE GATE
BUTTERFLY VALVE
EXISTING ROCK LEDGE
FINAL ROCK LEDGE
A
B
N

PLAN



SECTION A-A



SECTION B-B

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

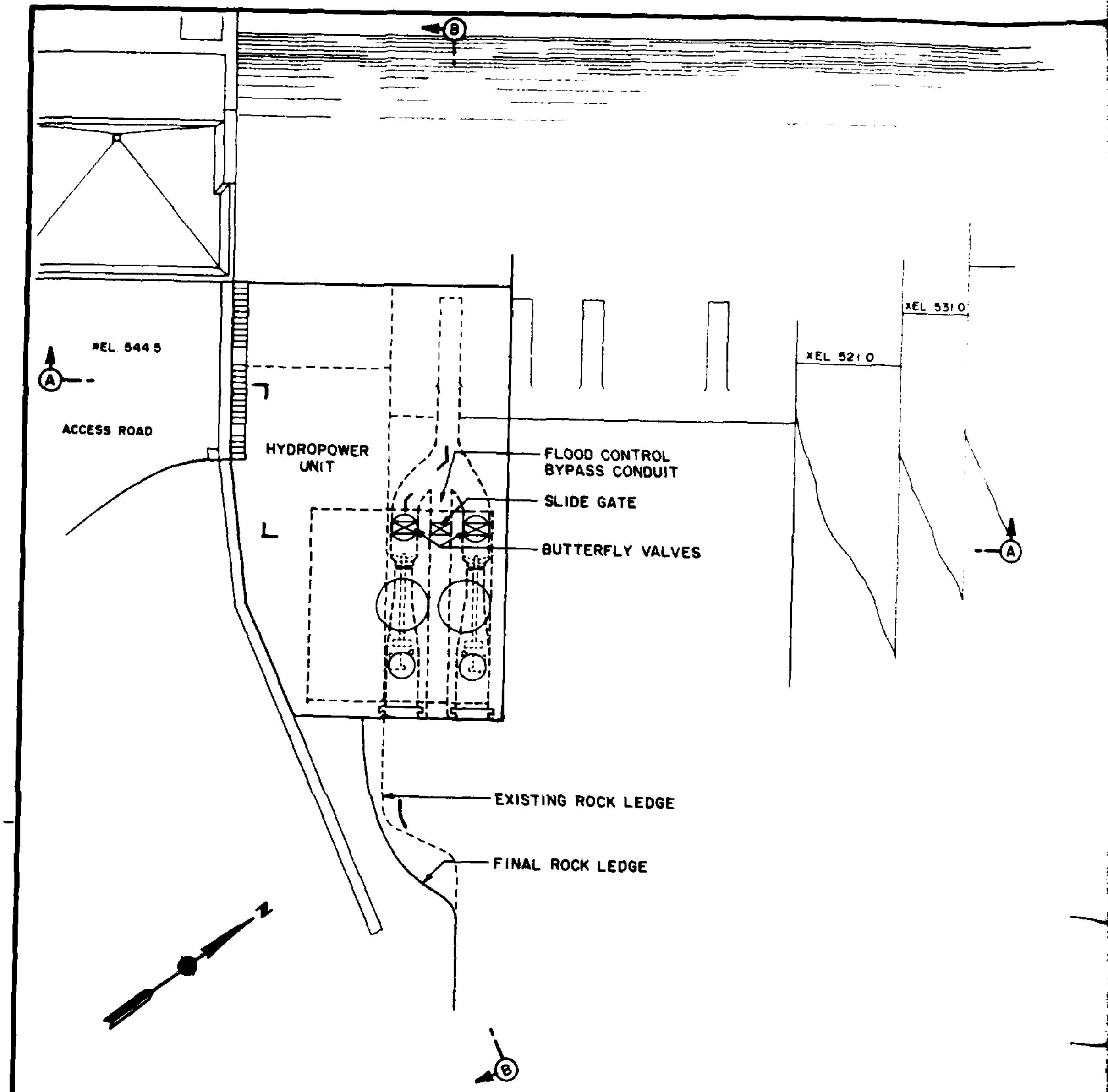
BLACKWATER RIVER LAKE

HYDROPOWER STUDIES

POWERHOUSE PLAN & SECTIONS

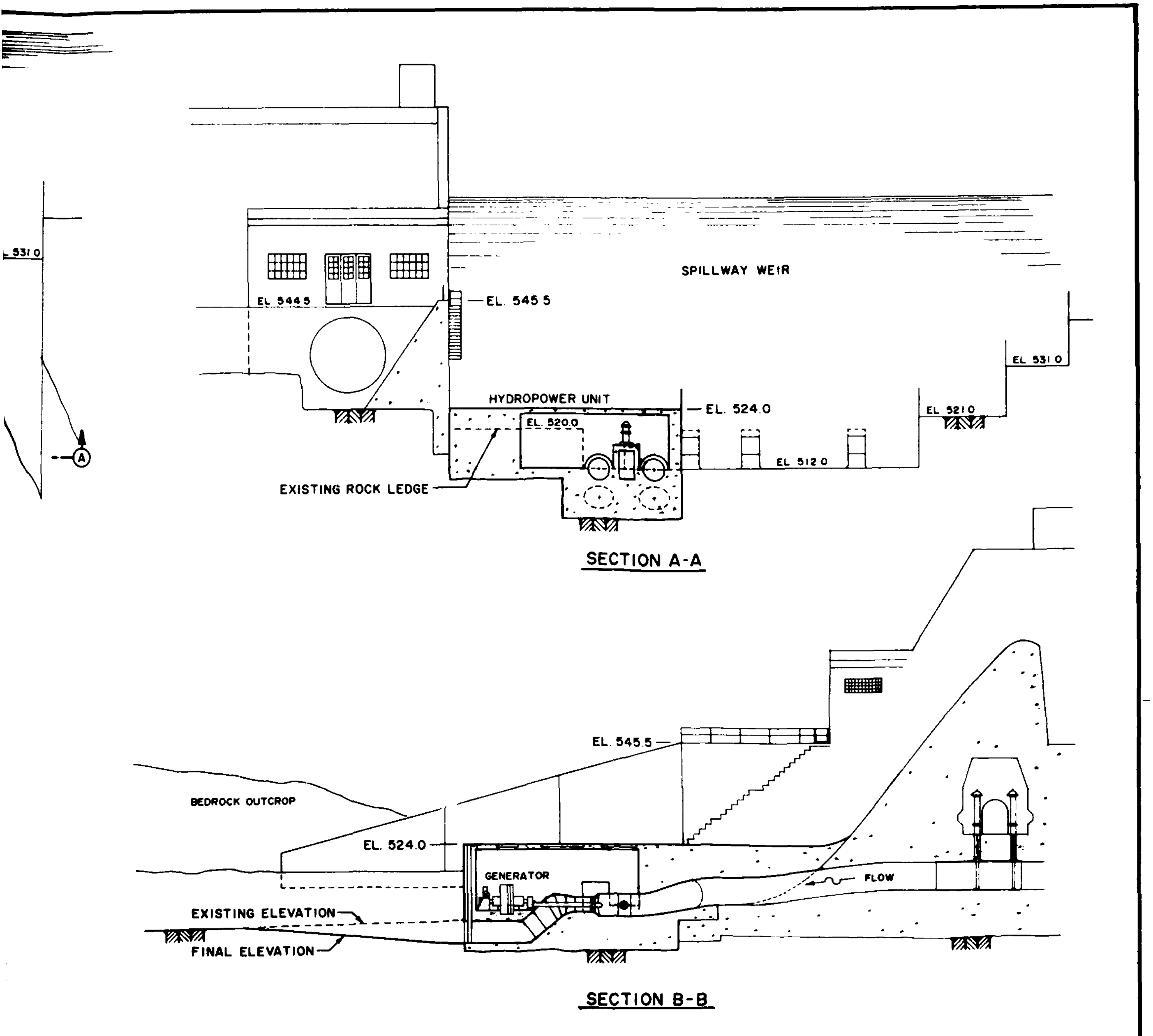
BLACKWATER RIVER NEW HAMPSHIRE

FIGURE 7



×EL 544.5
ACCESS ROAD
HYDROPOWER UNIT
FLOOD CONTROL BYPASS CONDUIT
SLIDE GATE
BUTTERFLY VALVES
×EL 531.0
×EL 521.0
EXISTING ROCK LEDGE
FINAL ROCK LEDGE
N
A
B

PLAN



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

BLACKWATER RIVER LAKE

HYDROPOWER STUDIES

POWERHOUSE PLAN & SECTIONS

BLACKWATER RIVER NEW HAMPSHIRE

FIGURE 8

Creation of the 28-foot deep permanent pool would require the clearing of about [illegible] acres in the existing reservoir. The purpose of the pool is to create a head, not to provide storage. Figure 9 shows the permanent pool envisioned as well as reservoir area capacity curves.

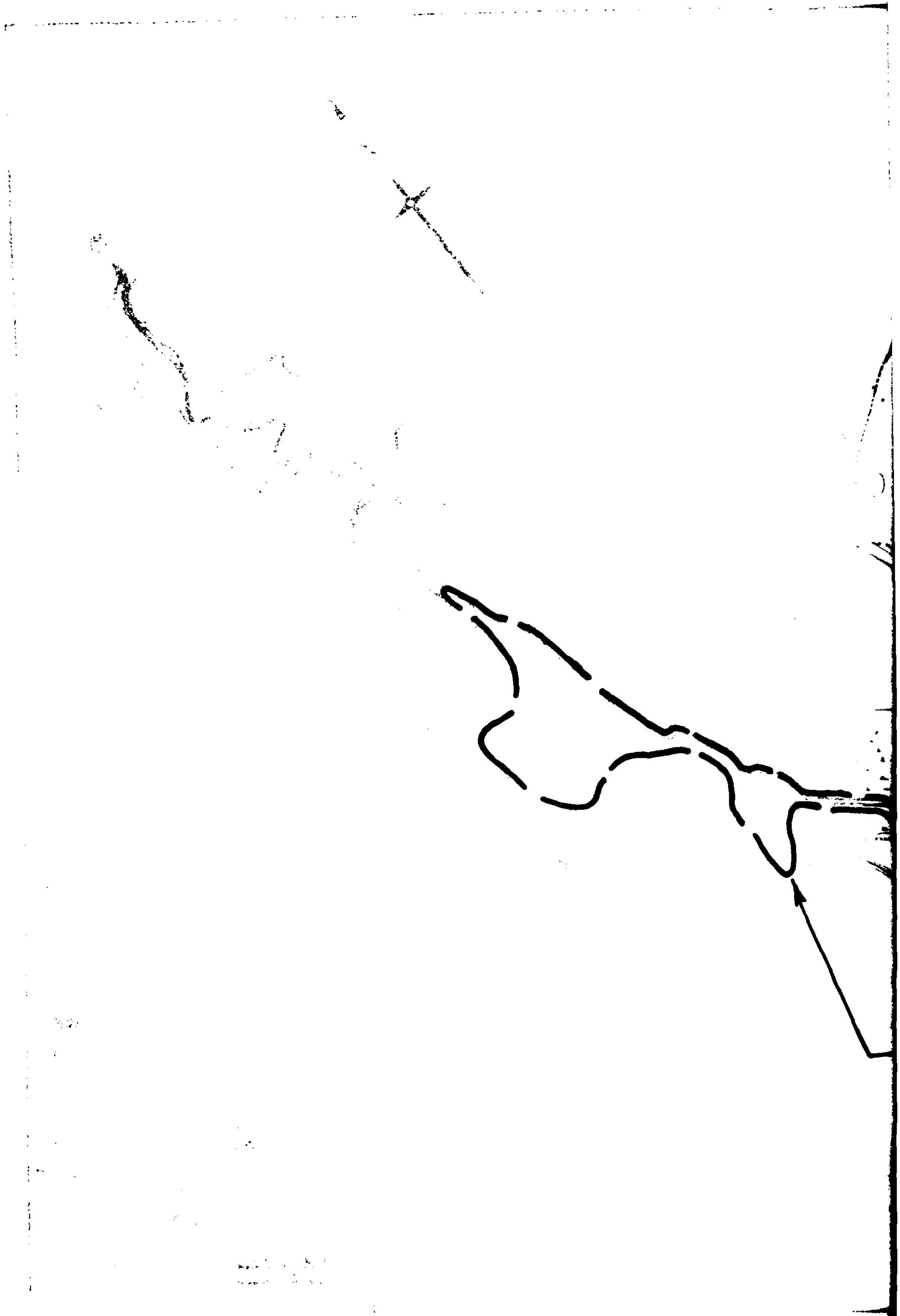
Due to the seasonal low flow character of the Blackwater River and the lack of hydropower storage for seasonal storage regulation, any run-of-river hydropower development would have to be viewed generally as a fuel saver with little dependable capacity associated with it. Though capacity would not be dependable, it is noted that with a permanent pool, the hydropower installation would be capable of providing "spinning reserve" capacity for emergency short term generation.

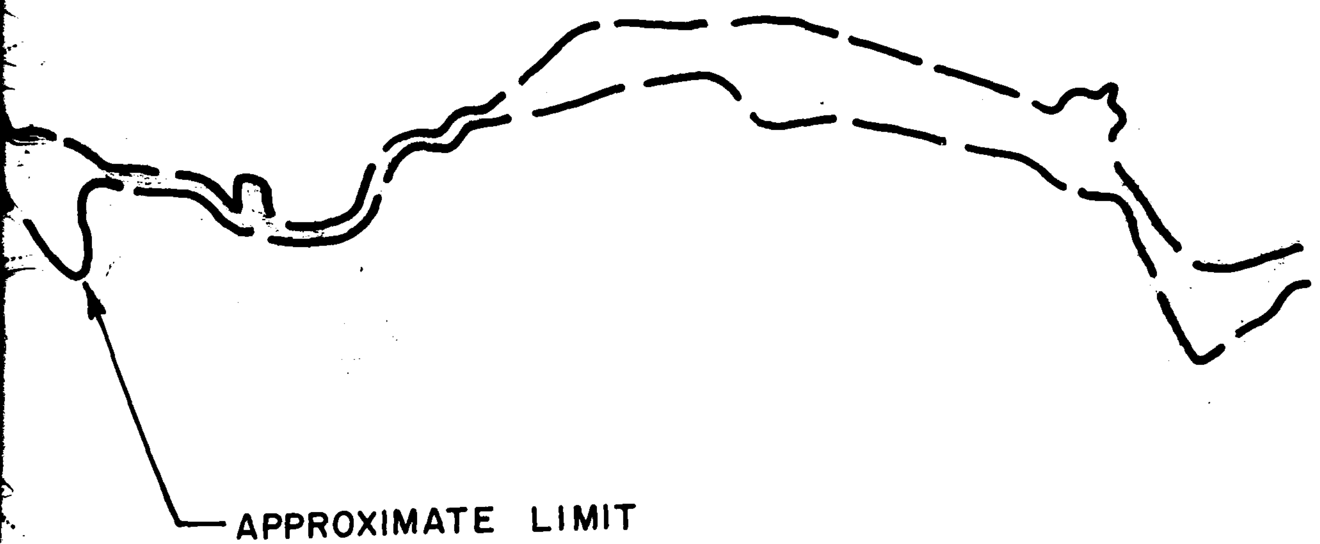
Any fluctuations in the head pool level, as a result of a run-of-river hydropower operations at Blackwater, would be caused by the variations in loading on the plant. With a pool depth of 28 feet (elevation 543 NGVD), the head pool will have a surface area of about 600 acres. Therefore, with a hydropower capacity of about 300 cfs, the maximum rate of change in pool level, as a result of "on and off" hydropower operations, would not exceed 0.2 foot per hour. Greater rates of pool fluctuation would occur periodically as a result of short term flood control operations. It would be expected that pool fluctuations, as a result of hydropower operations, would generally not exceed 1 to 2 feet; however, greater fluctuations would be experienced during flood regulation.

In 1939 the Corps completed a brief study of the feasibility of making Blackwater Dam a peaking hydropower facility which would provide energy and capacity as part of the initial project.

In 1954 as part of the New York-New England Interagency Committee resource study a plan of development similar to the Corps' 1939 alternative was considered. Due to the scope of the current study, no new work has been undertaken with regard to the alternatives developed in 1939 or 1954. However, the major elements of the 1939 concept are described below.

The project would require that the spillway crest be raised 18 feet from elevation 566 NGVD to elevation 584 NGVD. This measure would result in a total storage capacity of 115,000 acre-feet (16.9") at Blackwater. Forty-six thousand acre-feet (6.8") of flood control storage would be provided between elevations 573 and 584 and 69,000 acre-feet (10.1") of storage below elevation 573 would be available for power and conservation. A 10,000-foot long penstock would be built from Blackwater Dam to a powerhouse site at Snyder's Mill. Raising the dam and adding the penstock would result in a power head of about 200 feet. About 1,300 acres of land would have to be acquired and a short section of secondary road would have to be raised. The installed capacity would be 10,000 kw with an average annual energy output of about 22 million kilowatt hours. The plant factor would be approximately 20 percent and the project would be operated as a




APPROXIMATE LIMIT

peaking project, with 8,600 kw of dependable capacity. In 1939 the project had a benefit-to-cost ratio slightly in excess of unity. Under provisions of the Flood Control Act of 1936, after consultation with the Federal Energy Regulatory Commmission (at that time known as the Federal Power Commission) the Corps added minimum features to the dam (a 16-foot penstock intake) so as not to preclude the addition of hydropower facilities at Blackwater at some future time if a sufficient need for potential power existed. As previously stated, no work was done on this alternative for this report.

Hydropower Estimates

The hydropower potential of a volume of water is the product of its weight and the vertical distance it can be lowered. Water power is the physical effect of the weight of falling water. The function of a water power facility is to transform this gravitational potential energy into mechanical energy, by turning a turbine, for utilization in creating electrial energy with a generator. This potential rate of power generation, normally measured in kilowatts, is determined by the formula:

$$P = \frac{EHQ}{11.8}$$

where:

P = Power or capacity in kilowatts
E = Combined turbine and generator efficiencies
Q = Rate of discharge in cubic feet per second
H = Net hydraulic head in feet

With today's highly efficient turbines and generators, an average combined efficiency of 80 percent can be reasonably assumed for a typical range of operating head and discharge conditions. The potential amount of power generation over a period of time, "energy", is normally measured in kilowatt-hours and is equal to the average capacity times the duration of generation.

The potential amount of water power of any stream, river or lake is a function of: (1) the average annual streamflow, and (2) the average annual hydraulic head. Both the rate of discharge and the head are quantities which may fluctuate; therefore, it is the magnitude of these two quantities and their variability that determine the potential energy of a site and its dependability.

Based on 47 years of streamflow records on the Blackwater River at Webster, New Hampshire, the average flow is 213 cfs. Maximum annual runoff was 34 inches, in 1973, and the minimum annual runoff was 9 inches in 1965. A summary of average, maximum and minimum monthly flows recorded at this station is listed in Table 6.

TABLE 6

Average Monthly Flows (45 Years Through 1979)
Blackwater River in Webster, New Hampshire
(Drainage Area = 128 Square Miles)

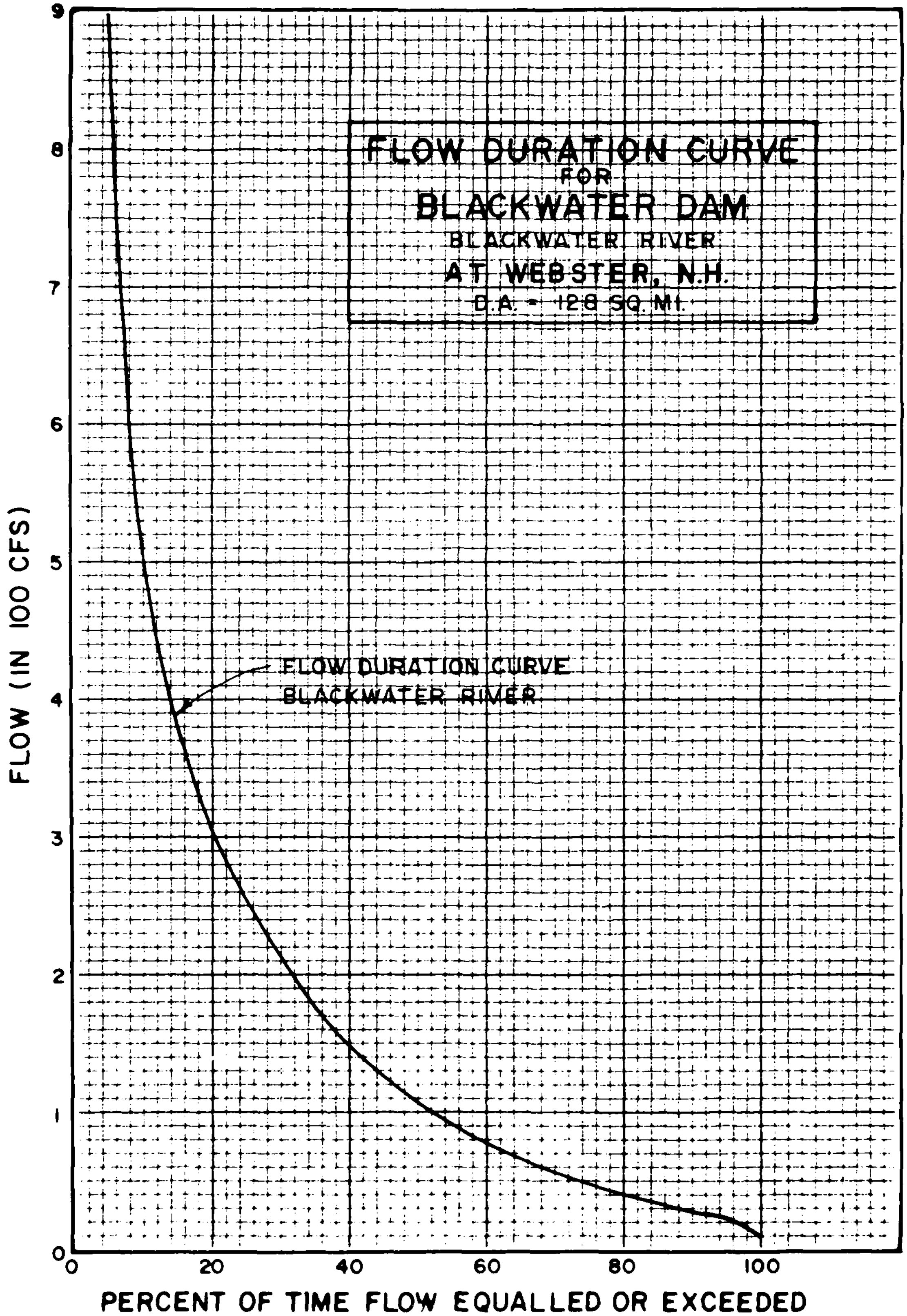
Month	Average Flow cfs	Average Flow inches	Percent of Annual Runoff	Maximum Monthly cfs	Maximum Monthly inches	Minimum Monthly cfs	Minimum Monthly inches
January	164	1.47	6.5	455	4.09	44	0.39
February	159	1.28	5.7	484	3.91	42	0.34
March	350	3.13	13.9	1,394	12.45	50	0.45
April	698	6.04	26.8	1,249	10.80	256	2.21
May	368	3.28	14.6	746	6.67	106	0.95
June	173	1.50	6.7	380	3.29	45	0.39
July	84	0.75	3.3	436	3.89	19	0.17
August	56	0.50	2.2	192	1.72	10	0.09
September	69	0.61	2.7	710	6.14	11	0.10
October	88	0.78	3.5	293	2.62	31	0.17
November	165	1.39	6.2	462	4.00	38	0.33
December	198	1.77	7.9	557	4.98	50	0.45
ANNUAL	213	22.54		322	34.02	84	8.84

A flow duration curve (discharge rate versus percent of time) for the USGS gage located at Webster, New Hampshire is shown on Figure 10.

Since the flow duration curve is a measure of the magnitude and variability of flow, the area under the flow duration curve - within the operating limits of the selected facility - establishes the potential average annual energy to be realized at a site. There is presently no permanent pool at Blackwater Dam; therefore, there is presently no hydraulic head for the generation of power. Creating a pool to elevation 543 feet NGVD would provide a 28-foot pool and represent a loss of 4,720 acre-feet (or approximately 10 percent) of the flood control storage. With an average annual flow of 213 cfs, the theoretical potential maximum annual energy would be 3,795 megawatt-hours. For this study an assumed hydraulic head of 30 feet was used in all hydropower computations.

There are two basic classes of hydraulic turbines - impulse and reaction turbines. The fundamental difference is that impulse turbines are driven by the kinetic energy of a high level of velocity jet, whereas reaction turbines are driven by the combined pressure and velocity of the water.

The impulse design has cost-effective operating characteristics for high heads (800 feet and higher) and is not suitable for Blackwater Dam. Reaction turbines have two basic types of runners - Francis and



FLOW DURATION CURVE
FOR
BLACKWATER DAM
BLACKWATER RIVER
AT WEBSTER, N.H.
D.A. = 128 SQ. MI.
FLOW DURATION CURVE
BLACKWATER RIVER
FLOW (IN 100 CFS)
PERCENT OF TIME FLOW EQUALLED OR EXCEEDED
0
1
2
3
4
5
6
7
8
9
0
20
40
60
80
100

FIGURE 10

Propeller runners. The Francis-type runner is more applicable to higher head installations and the Propeller runner can operate at heads up to 100 feet but is usually most cost-effective at heads of 60 feet or less. Both the Francis and Propeller turbines can be used in a horizontal or vertical plane. There are also Propeller turbines of slant design and tubular design. Propeller-type units provide for high operating speed. Considering the hydraulic head, the variability of flow, and the "run-of-river" type operation that would take place at Blackwater, standard tube-type Propeller turbine units were assumed for both alternatives. The operating range of these turbines is 40 to 105 percent of the design discharge. Characteristics of the various turbine types and sizes were obtained from manufacturer literature and the July 1979 Corps of Engineers report entitled "Feasibility Studies for Small Scale Hydropower Additions - A Guide Manual."

Generators are either synchronous or induction types. The synchronous unit is equipped for self-excitation and synchronization before going onto the grid, whereas, the induction generator relies on power from the grid for excitation. Induction generators are somewhat cheaper and more applicable to small installations; however, utility companies are reluctant to have numerous small units in the system capable of draining power from the grid for excitation. Therefore, for this reconnaissance study, synchronous generators were assumed for both alternatives. Generators would have rated capacities equal to or greater than the rated turbine capacity and also be capable of operating continuously at a 15 percent overload.

Based on the assumptions described above, and flow duration analysis for the USGS gage at Webster, New Hampshire, hydropower estimates were made for the two alternatives under study.

Alternative 1 would consist of one 600-kilowatt standard, tube-type turbine capable of discharging 295 cfs under a head of 30 feet. This turbine would be equipped with a synchronous generator with not less than 600 kilowatt capacity. The potential average annual "energy" production would be 2,013,315 kilowatt hours, at an average annual plant factor of 38 percent. Generation would occur whenever flows were in the 118 cfs to 310 cfs range.

Alternative 2 would consist of twin 360-kilowatt standard, tube-type turbines each capable of discharging 177 cfs under a head of 30 feet. The units would be equipped with synchronous generators with not less than 360 kilowatt capacity each. The total hydraulic capacity would be 354 cfs at a head of 30 feet capable of generating 720 kilowatts of power. The potential average annual "energy" production would be 2,512,190 kilowatt-hours, at an average annual plant factor of about 39 percent. With the Alternative 2 installation, generating flows would range from a low of about 70 cfs to a high 370.

Comparative data for both alternatives are shown in Table 7.

TABLE 7

Blackwater Dam
Hydropower Development
Alternatives 1 and 2
Pertinent Data

	Alternative 1	Alternative 2
Number of units	1	2
Throat diameter (feet)	4.2	3.3
Hydraulic head (feet)	30	30
Hydraulic capacity (cfs)	295	354
Generator type	Synchronous	Synchronous
Generator capacity	600 kw	360 kw each 720 kw total
Potential annual generation (kwh)	2,013,315	2,512,190
Plant factor	0.383	0.398
Turbine/generator efficiency	80%	80%
Type of turbine	Standard tube	Standard tube

Cost Estimates

Cost estimates contained in this section have been prepared either by using standardized cost curves taken from the Corps publication entitled "Feasibility Studies for Small Scale Hydropower Additions" or by preparing site specific estimates using standard engineering practices. Estimates of first costs for Alternatives 1 and 2 are presented in Table 8 below.

Standard tube turbine units would be used for either alternative. Slide gates are included for dewatering the units. No switchyard is needed for either level of development and a one-mile transmission line utilizing existing poles is included. No crane is provided since a truck mounted unit could readily be used at the site. No new roads or road relocations are needed.

Reservoir clearing costs have not been included in this estimate. It is estimated that complete reservoir clearing would cost around $800,000. However, preliminary indications are that timber harvesters would pay around $300,000 for the right to harvest the wood. It is assumed that the tree stumps and topsoil could be left in place and that the slash from timber harvesting and unusable wood products could be removed for less than $300,000. As the study progresses, water quality investigations may show that leaving topsoil and tree stumps could cause unaccceptable environmental impacts. If such findings are made, costs of complete clearing will be included in future reports.

TABLE 8

First Costs for Alternatives 1 and 2

Item	Alternative 1	Alternative 2
Drainage	-	-
Grading	-	-
Access	-	-
Miscellaneous Features	$ 4,150	$ 4,150
Penstock	17,500	17,500
Bifurcations	12,500	15,000
Gates and Valves	18,000	18,000
Tailrace	44,000	55,000
Spillway	-	-
Miscellaneous Mechanical Equipment	30,000	35,000
Powerhouse Excavation	25,000	27,000
Concrete	253,000	253,000
Miscellaneous	27,000	48,000
Cofferdam	10,000	10,000
Dewatering	23,000	23,000
Diversion	-	-
Turbine and Generator	480,000	870,000
Switchyard	-	-
Station Electrical Equipment	91,000	110,000
Transmission	10,000	10,000
SUBTOTAL	$1,045,150	$1,495,400
20% Contingencies	209,030	299,080
TOTAL	$1,254,180	1,794,480
Say:	$1,250,000	$1,800,000

For this report hydropower additions at Blackwater Dam are assumed to have an economic life of 50 years. Currently, as prescribed by law, Federal agencies use a 7-3/8 percent interest rate to determine economic feasibility. Construction time for the alternatives under consideration would be about 18 months and, therefore, no interest during construction is included. Based on these assumptions annual costs are shown in Table 9.

TABLE 9

Annual Costs for Alternatives 1 and 2

Item		Alternative 1	Alternative 2
First cost		1,250,000	1,800,000
ED/S&A		220,000	315,000
Total Investment		1,470,000	2,115,000
I&A (.07591)		111,588	160,550
OM&R		27,000	30,000
Annual Costs	Say	138,600	190,600
*Energy Production Cost $\left(\frac{\text{mills}}{\text{kwh}}\right)$		69	76

*This assumes annual average usable energy generation of 2,013,315 kwh for Alternative 1 and 2,512,190 kwh for Alternative 2.

IV. EVALUATION OF PLANS

Economic Evaluation

The purpose of this section is to evaluate the economic benefits which will accrue to certain hydropower additions at Blackwater Dam.

The conceptual basis for evaluating the benefit from energy produced by hydropower plants is society's willingness to pay for these outputs. In the absence of direct measures of willingness to pay, such as marginal cost pricing, the benefit from energy produced by hydroelectric power plants is measured by the resource cost of the most likely alternative to be implemented in the absence of the hydroelectric plant. The Federal Energy Regulatory Commission (FERC) has indicated the alternative of an oil-fired combined cycle generating station to be most likely in the absence of hydroelectric facilities at Blackwater Dam. The costs of the oil-fired alternative were estimated by FERC. The costs of the hydroelectric alternatives were estimated by the New England Division and include project first costs, operation and maintenance costs and transmission line costs.

When FERC estimates the costs of the thermal alternative, two costs are addressed, the capacity and the energy cost. The addressed measure of the value of the hydropower project's generating capacity is the total of the thermal plant's amortized investment cost, transmission costs, interim replacement costs, and fixed operating and maintenance costs. The measure of the values of the hydropower project's energy production is the total of the thermal plant's variable operation and maintenance costs and fuel costs. Since there is no dependable generating capacity associated with run-of-river hydropower additions, only the energy value is taken as an economic benefit. Using conventional power value calculation methods in June 1981 FERC found that for an oil-fired combined cycle alternative the corresponding hydroelectric energy value for hydropower would be about 72 mills/kwh.

In December of 1979 the "Water Resources Council (WRC)" which formulates the procedures used by Federal agencies to evaluate water resource projects indicated that real escalation in fuel costs should be considered when evaluating hydropower projects. Analyses which take into account real fuel cost escalation are referred to as relative price shift or inflation-free life cycle analyses. FERC also determined an energy value using this method and found, that when projected real oil cost changes are considered, the value of run-of-river energy produced at Blackwater Dam is 142 mills/kwh.

The energy values reported here are taken from a letter dated 5 June 1981 from the Federal Energy Regulatory Commission. The letter is contained in the Correspondence Appendix. Table 10 shows benefits for Alternatives 1 and 2 based on power values provided by FERC.

TABLE 10

Annual Benefits (With Oil Price Changes)

Project	Energy Benefit	Capacity Benefit	Total
One 600 Kw Unit	2013315 (.142)	0	285891
Two 360 Kw Units	2512190 (.142)	0	356731

Project Benefits (Without Oil Price Changes)

Project	Energy Benefit	Capacity Benefit	Total
One 600 Kw Unit	2013315 (.072)	0	144959
Two 360 Kw Units	2512190 (.072)	0	180878

Utilizing costs from the previous section benefit to cost ratios are provided in Table 11 below for all possible cases.

TABLE 11

Benefit-to-Cost Ratios

Project	Without Oil Price Changes	Including Oil Price Changes
One 600 Kw Unit	$\frac{144959}{138600} = 1.0$	$\frac{285891}{138600} = 2.1$
Two 360 Kw Units	$\frac{180878}{190600} = 0.9$	$\frac{356731}{190600} = 1.9$

The Water Resources Council requires analyses which include the effects of changing fuel prices. The computation of benefit-to-cost ratio without taking into account oil cost changes is shown for sensitivity analysis only. The alternatives being considered are economically efficient using the current approved method of analysis.

Social, Economic, Cultural, and Recreational Considerations

Socioeconomic

Since these two alternatives would not involve any major structural additions or alteration, social impacts would be insignificant during construction. Maintaining the pool at elevation 543 would cut off the Peter's Bridge route to the Scribner's Corner Area. However, there is other access to the area. The major social concerns of the project center around the proposed 600 acre pool. The creation of this pool would offer

excellent potential for the development of new recreational opportunities. In the past, residents have opposed the creation of the pool fearing this type of development would result in a highly commercialized recreational area and destroy the unique character of Webster and Salisbury. However due to the relatively small pool area of 600 acres, as compared to the previously proposed pool of 2020 acres, it is expected that recreational development will not lead to significant commercialization in the area. While additional facilities for fishing, camping, and swimming would be constructed they are not expected to result in a large influx of people. Rather, these facilities would most likely be utilized by New Hampshire residents living within proximity to the pool. Furthermore, in Merrimack County, there are already six established public recreational areas, (of these six areas, three are near the Blackwater Reservoir). These areas are expected to be more heavily utilized than Blackwater.

Historical and Archaeological Resources

While there are no recorded prehistoric sites within the Blackwater Dam Project, there is a high probability that unrecorded sites exist. As part of an ongoing program of historic and archaeological resource survey in New England Division properties, a "Cultural Resource Reconnaissance" of the Blackwater Dam property is tentatively scheduled for the summer of 1984. Should hydropower development studies proceed to stage 3 planning prior to that date a reconnaissance of the area affected by plant construction or power pool inundations and fluctuations will be necessary.

Of the approximately 25 recorded historic period sites at Blackwater Dam, 9 farmstead sites, one former cemetery location, a public meeting hall site and a sawmill site would be permanently inundated by a power pool of 543 feet NGVD or potentially affected by powerhouse construction. The archaeological and historic reconnaissance described above would include a survey to locate any unrecorded historical sites, and determine more clearly the nature and condition of these recorded sites.

Recreational and Natural Resources

The proposed project would have adverse impacts on the existing recreational use of the reservoir area, but also offer excellent potential for development of new recreation opportunities.

Creation of a 600 acre pool would have no effect on the existing, Corps managed, roadside picnic area or sightseeing, but would eliminate approximately half of the snowmobile trail system; about nine miles of cold water trout fishing habitat and canoeable river; about 600 acres of wildlife habitat including some woodcock cover, wetlands and fields; and the local swimming holes. These impacts on existing recreational use would probably be considered severe by local interests and could generate heavy opposition unless satisfactorily mitigated.

However, creation of a lake with a relatively stable water level would provide the potential for development of new recreation opportunities which could partially mitigate the loss of existing resources as well as replace some of the lost recreation with new facilities. Snowmobile trails could be relocated around the lake, a good lake fishery could be established with boat launching access points, swimming beaches could be constructed and additional day-use recreation could be provided, if desired, along with camping facilities. There is probably little that can be done to mitigate the loss of wildlife habitat and hunting other than improved wildlife management.

When the original Blackwater Dam Master Plan was prepared in 1967, there was overwhelming opposition to creation of the proposed 2020 acre recreation lake and attendant recreation facilities including camping areas, swimming beaches and boat launching ramps. Whether the same degree of opposition would still be present in regard to creating a smaller lake for hydropower purposes, with or without recreation facilities, is unknown, although there are current indications of opposition to any major recreational development at Blackwater Dam.

Environmental Considerations

Environmental considerations are based on development of the proposed 600 acre pool with a maximum depth of 28 feet at the dam. No pool presently exists at the dam. Hydropower facilities constructed at Blackwater Dam could cause daily pool fluctuation due to hydropower operation of one-half to one-foot per twelve hour operating period.

The permanent reservoir pool located in back of the dam would result in a modification of the erosion pattern during flood control operations. Areas less frequently (or never) inundated may be reached by the waters more often and provide increased opportunity for erosion, particularly in the early years of operation. Erosion at the pool could be significant, but should be restricted to a narrow area along the shore due to the minimal nature of the fluctuations caused by hydropower operation.

The development of the proposed 28-foot deep pool (maximum) for hydropower generation should cause only minimal changes in the existing water quality. The reasoning for this assumption is based on several items, which include the relatively shallow depth of the pool (less than 35 feet deep), the short detention time (about 8 days under average flow conditions) and the fact that the river is naturally sluggish in the project area. As a result of the shallow depth and short detention time, there should be little if any thermal stratification effect in the reservoir and it is questionable at this time if detailed thermal stratification studies or modeling would be required to determine the need for a multiple level withdrawal outlet works. Problems may occur with suspended solids and turbidity if the vegetation and top soil are not

stripped from the pool area, or if considerable erosion takes place upstream during flood control operations.

Future studies will be directed towards the determination of the extent of reservoir site preparation, the need for selective withdrawal capability at the project, subsequent design of a multilevel outlet structure, and the detailed analyses for prediction of water quality conditions in the reservoir and downstream.

Project development would eliminate about 9 miles of riverine aquatic habitat, and the associated cold water fishery. It would be replaced by a 600 acre surface area pool and its warm water habitat, capable of supporting appropriate warm water species. Artificial reefs or cribbing could be introduced to enhance fish habitat.

The 600 acre pool would permanently inundate all vegetation within it. Areas undergoing more frequent inundation than previously, during flood control operations, would experience the killing of less flood tolerant species and a gradual shift in composition toward more tolerant species.

Wildlife associated with the permanently inundated habitats would perish or move onto adjacent lands where increased competition would cause mortality of some. Displacement and some mortality would also take place in areas of increased frequency of inundation. The population shifts may cause overcrowding and further mortality in some areas where the habitat carrying capacity has been reached. However, it would be possible to increase migratory waterfowl habitat by planting rice or other food crops along the shoreline.

Since there are no currently listed Federal threatened or endangered species in the project area, no impacts would be anticipated from implementation of the project.

Reservoir Regulation

If hydropower facilities are eventually built at the site, the primary purpose of the project will remain flood control, and all flood control activities will override the requirements of hydropower generation. This control would be retained by the Division Engineer through the Corps' Reservoir Control Center.

CONCLUSION

Based on the preliminary findings presented in this reconnaissance report it appears that the addition of hydroelectric generating facilities at the Corps' Blackwater Flood Control Dam is economically feasible. It has been determined that if a 28 foot, 600 acre, permanent pool were created at the project and a 600 kilowatt standard tube unit were installed, an average of 2013 megawatt hours of energy would be produced annually at a cost of about 69 mills per kilowatt hour. As this planning process continues detailed studies will be made to verify these findings, formulate alternative plans of development (including a reevaluation of the Corps plan developed in 1939) and ascertain environmental, social, recreational, real estate, and cultural impacts of various possible plans of development.

ACKNOWLEDGEMENTS

This study was conducted by the New England Division, Army Corps of Engineers, under the general supervision of Mr. Joseph L. Ignazio, Chief, Planning Division and Mr. Harmon H. Guptill, Chief, Hydroelectric Energy Studies Branch. Investigations were performed by an interdisciplinary project team. Persons primarily responsible for the contents of this report are: Robert LeBlanc, Project Manager; Edwin Blackey and James Blair, geotechnical aspects; Ben Piteo, Leon Fairbanks, Anthony Mackos and Anthony Sigel, design and cost estimates; Joseph Horowitz, environmental aspects; Donald Wood, water quality; Farrell McMillan, hydrologic and hydraulic aspects; John Wilson, cultural areas; Douglas Cleveland, recreation; Irving Fistel and Robert Heald, operational concerns; Joseph Finegan, reservoir regulation; Richard Ring, economics; Diane Halas and Audrey Nahabedian, socioeconomic aspects; and Camille Santi and Marianne Conway, report preparation.

Preparation and distribution of this report would not have been possible without the cooperation of the Division's technical, clerical and administrative staffs. Special thanks is extended to the entire Reprographics Branch staff.

CORRESPONDENCE

APPENDIX

FEDERAL ENERGY REGULATORY COMMISSION
NEW YORK REGIONAL OFFICE
26 FEDERAL PLAZA, ROOM 2207
NEW YORK, NEW YORK 10278

June 5, 1981

Colonel C.E. Edgar, III, Division Engineer
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254

Dear Colonel Edgar:

In accordance with your request of April 28, 1981, we have calculated generalized at-market power values at 10 percent intervals of capacity factors from 19 through 69 percent applicable to your hydropower studies of North Springfield Dam at North Springfield, Vermont, and Blackwater Dam at Webster, New Hampshire. In addition, we have estimated at-market power values for the alternative plan of development for Blackwater Dam. Under this scheme, Blackwater would have an installed capacity of 10,000 kW, dependable capacity of 8,600 kW, and an average annual generation of 22 million kWh, yielding a dependable capacity factor of 29.2 percent. Capacity and energy values were calculated at present price levels (May 1981), as well as on a life cycle cost basis for energy, using both federal interest of 7-3/8 percent and private cost of money of 12-1/2 percent. The power market area was taken to be New England. For those developments with plant factors less than 40 percent, oil-fired, combined cycle generating units were considered to be the most likely alternative. For plant factors equal to or greater than 40 percent, base load, coal-fired steam units were used.

Capital costs of a coal-fired generating plant consisting of two 600 MW units in New England is estimated at $950/kW under federal financing and $1.090/kW under private financing, while the capital cost of a single unit 400 MW combined cycle plant is taken at $420/kW under both types of financing. Heat rates are taken at 9,500 Btu/kWh for a base load coal plant and 9,000 Btu/kWh for the combined cycle alternative. Average fuel costs in the New England region as of May 1981 were approximately $7.80/million Btu's for No. 2 oil and $2.20/million Btu's for bituminous coal.

The life cycle cost analysis was based on a 100 year period beginning with the projects' expected on-line date of 1995. It was assumed that for the period 1981-2005, fuel costs would escalate according to Department of Energy projections. After 2005, they were assumed to increase along with the general rate of inflation, i.e., in constant dollars. All energy costs were discounted to the year 1995 to obtain their present worth. A capital recovery factor was then applied to yield the levelized annual energy cost.

Estimated at-market capacity and energy values, as of May 1981, and life cycle energy values are shown below. The capacity values, rounded to the nearest dollar, are applicable to the project's dependable capacity, and the energy values, rounded to the nearest mil, are applicable to the average annual generation.

	Generalized Power Values						
	Capacity Factor (%)						Blackwater
As of May, 1981	19	29	39	49	59	69	29.2% /1
Capacity - $/KW-YR							
Federal - 7-3/8%	69	69	69	142	142	142	69
Private - 12-1/2%	144	144	144	321	321	321	144
Energy-Mills/KWH							
Federal - 7-3/8%	77	73	72	22	25	27	73
Private - 12-1/2%	77	73	72	21	25	28	73
Life Cycle Cost							
Energy-Mills/KWH							
Federal - 7-3/8%	152	145	142	20	23	25	145
Private - 12-1/2%	146	139	135	21	24	27	139

/1 Dependable capacity factor

The value of incremental downstream energy benefits due to low flow augmentation provided by Blackwater is conservatively estimated at 41 mills/kWh, as of May 1981. On a life cycle basis, it is estimated at 96 mills/kWh under federal financing, and 69 mills for private financing.

If we can be of further assistance in your studies, do not hesitate to call on us.

Sincerely,

James D. Hebson

James D. Hebson
Regional Engineer

ATE

ME

83